TECHNOLOGY DEPT.

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THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

JULY 1956

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THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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TECH

DIAMOND WHEELS BY CARBORUNDUM

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Grinding time is reduced to the absolute minimum, when carbide-tipped tools are ground with diamond wheels by CARBORUNDUM. Heat generated during grinding is negligible, therefore there is less danger of cracking the sintered carbide tips. High surface finish at the cutting edges gives the tool maximum life between grinds and, consequently, less time out of service. Diamond wheel wear is negligible, and the amount of stock removed virtually equal to the amount of infeed—therefore the depth of grind is consistent around the full circumference of a multi-bladed cutter. This ensures an absolutely concentric circle of all the cutting edges at one setting, without need for continual measuring with a dial gauge, and re-setting to compensate for wear of the wheel.
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MINIMUM WEAR
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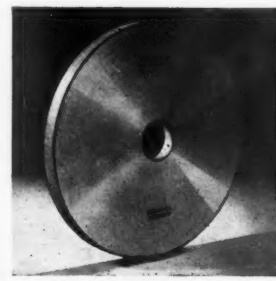

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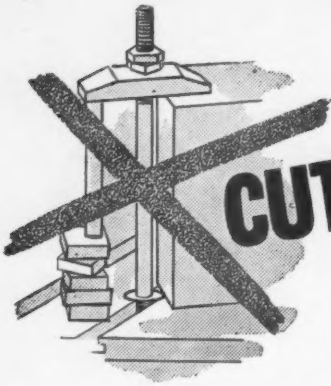

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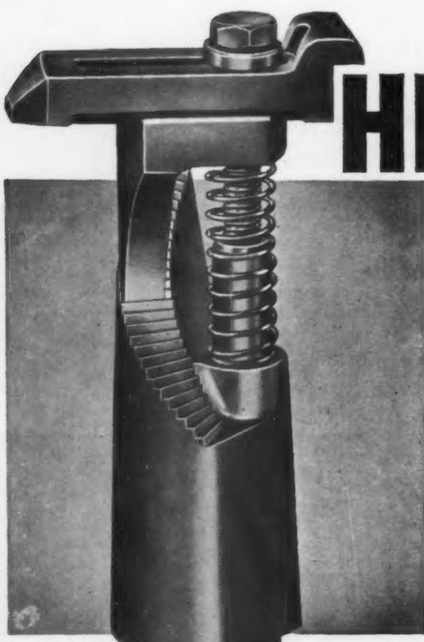

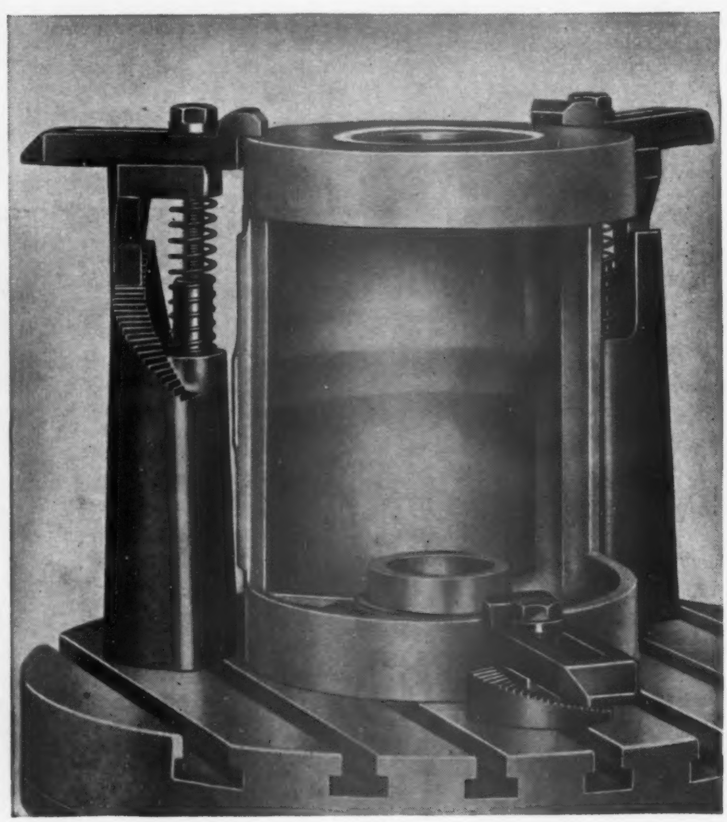

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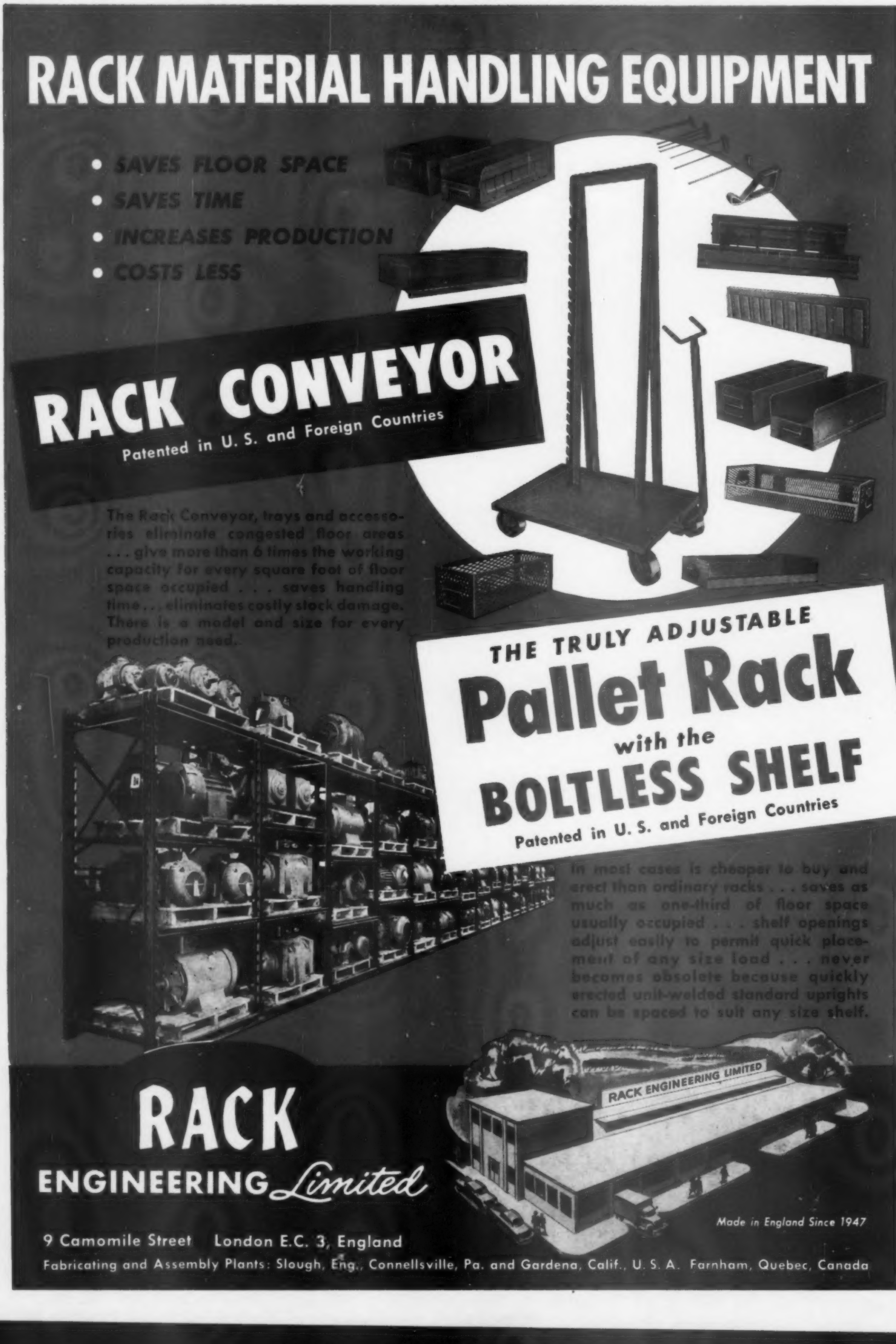
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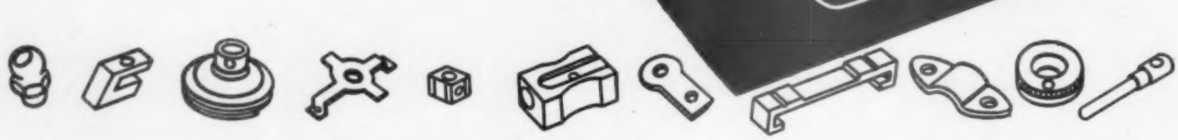

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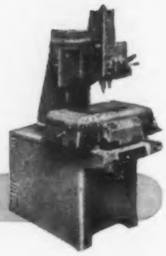

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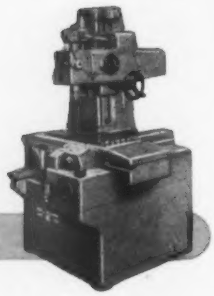

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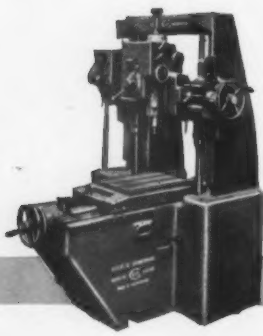

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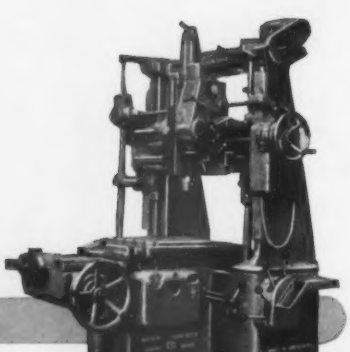

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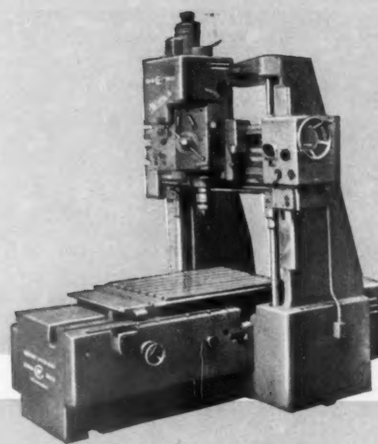

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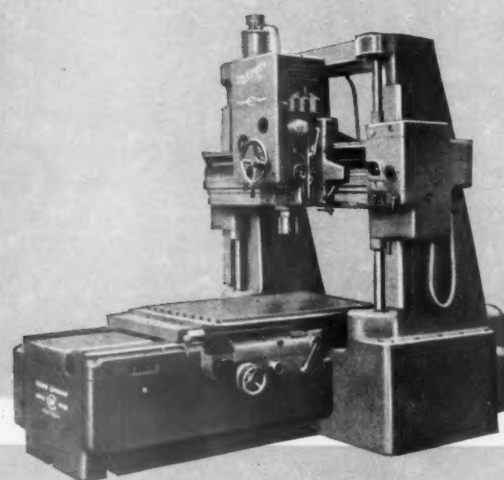

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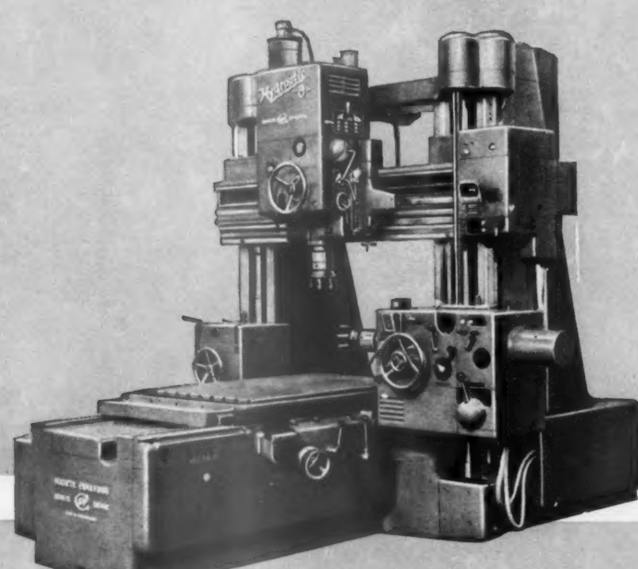

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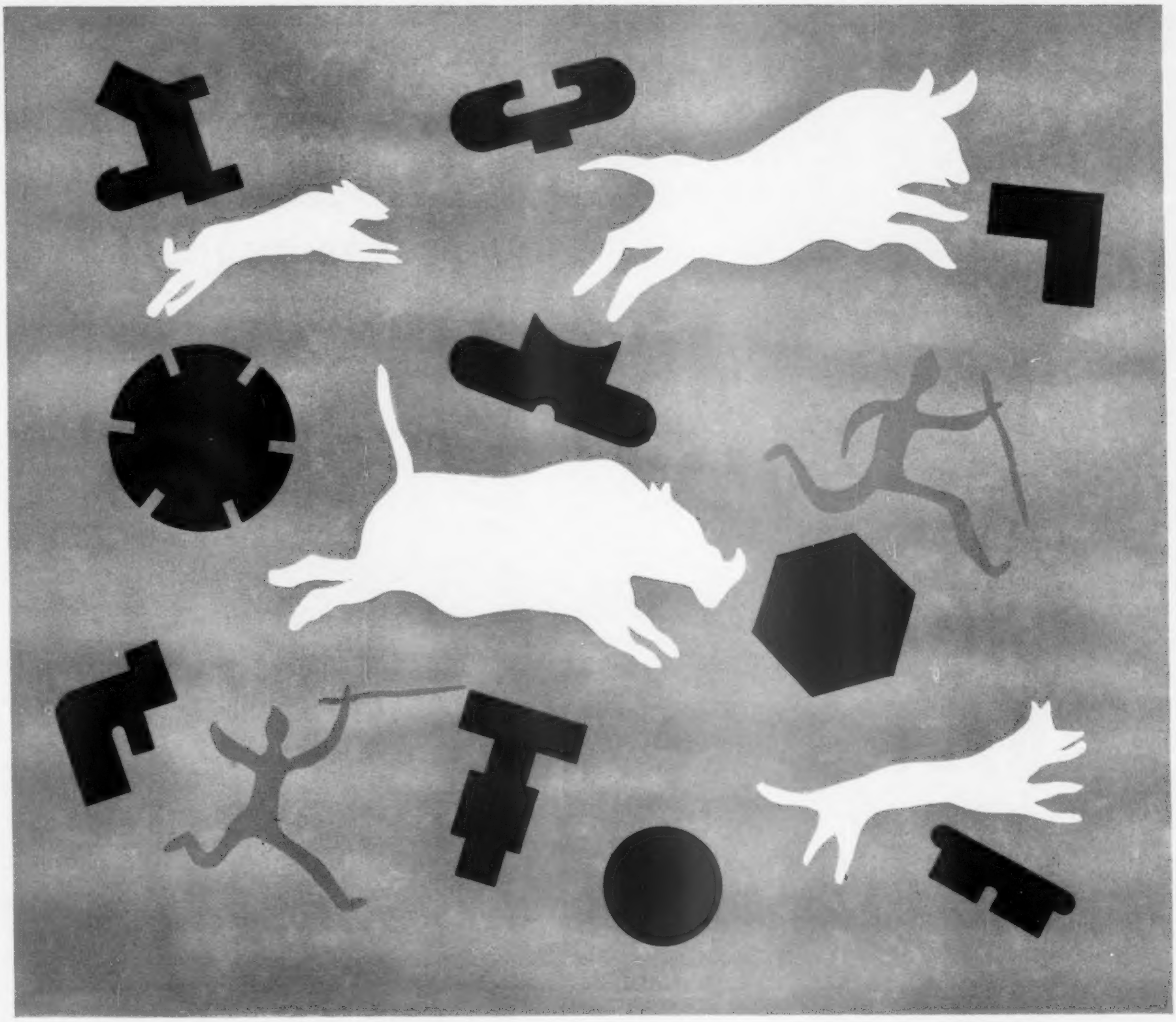

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Specified zones can be hardened under automatic control and with negligible distortion or scaling of the work. Quickly interchangeable, standardised control cams and inductors permit several different jobs to be run economically in successive batches.

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Hardening zone selection	Cam
Maximum hardening speed	1½"/sec.
Maximum return stroke speed ...	6"/sec.
Typical production (12" stroke) ...	300/hr.
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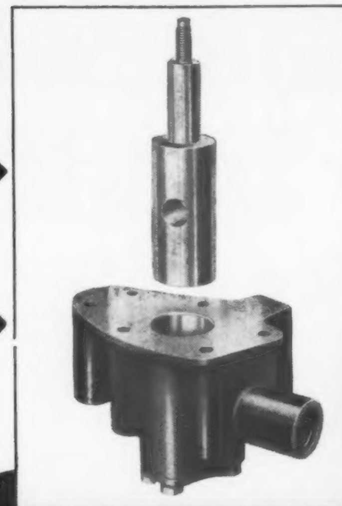
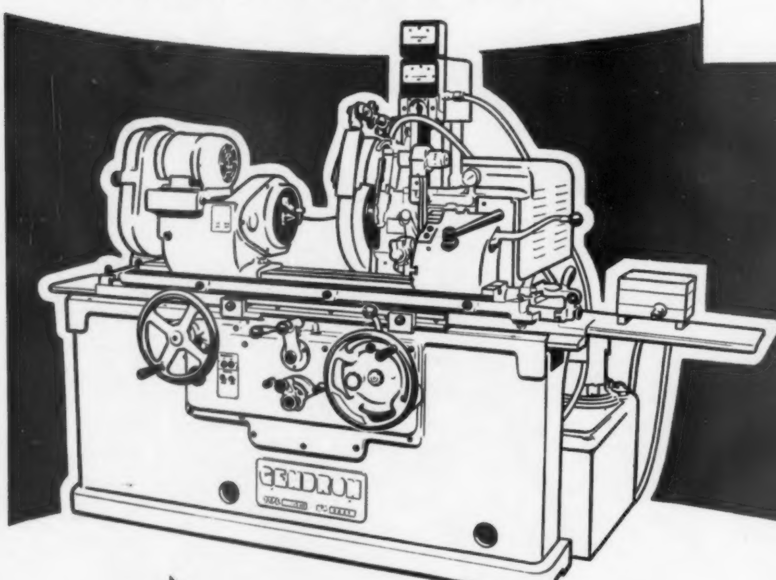


to make them fit parts like this . . →

WITH A CONSTANT CLEARANCE AND WITHOUT SELECTIVE ASSEMBLY ?



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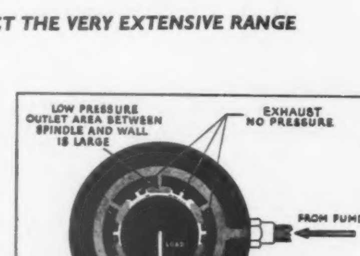

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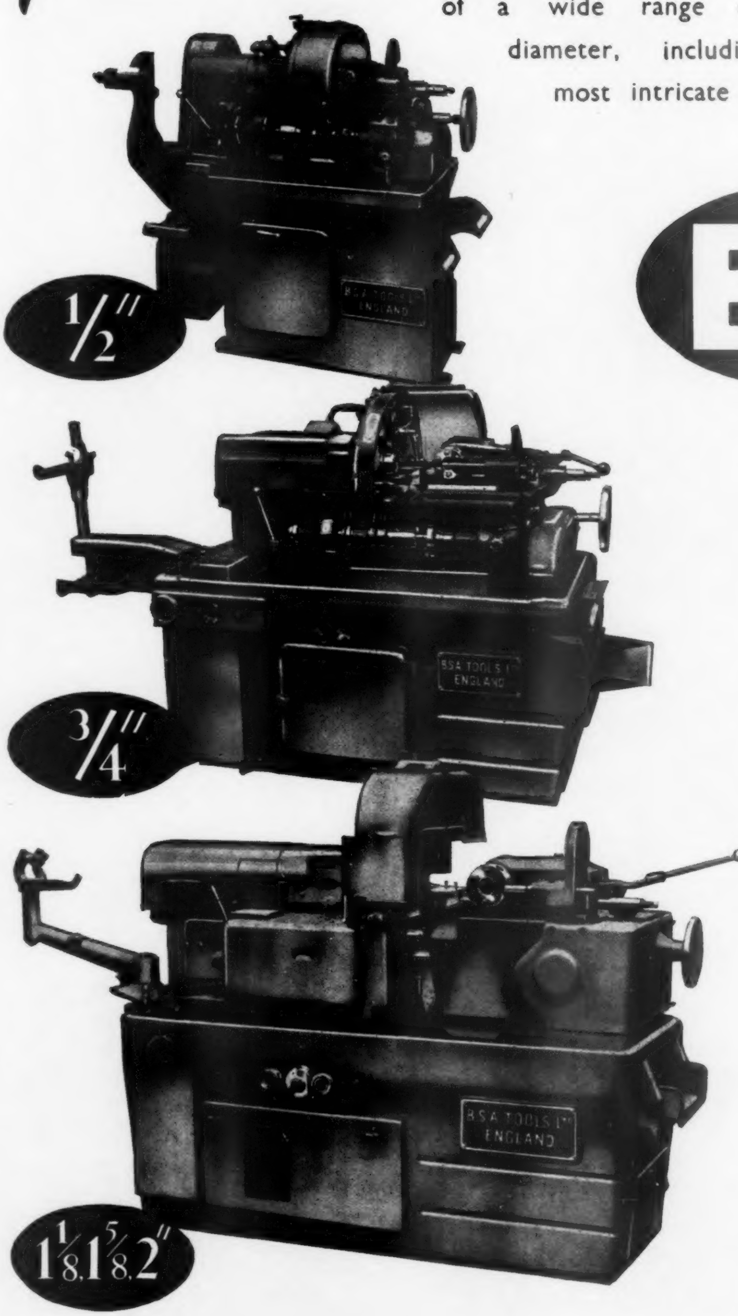
of a wide range of components up to 2 in. diameter, including those involving even the most intricate automatic machining operations



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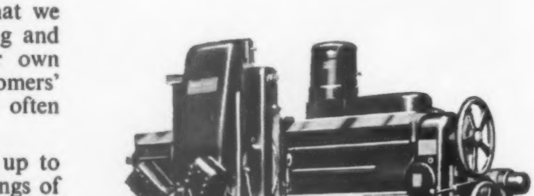

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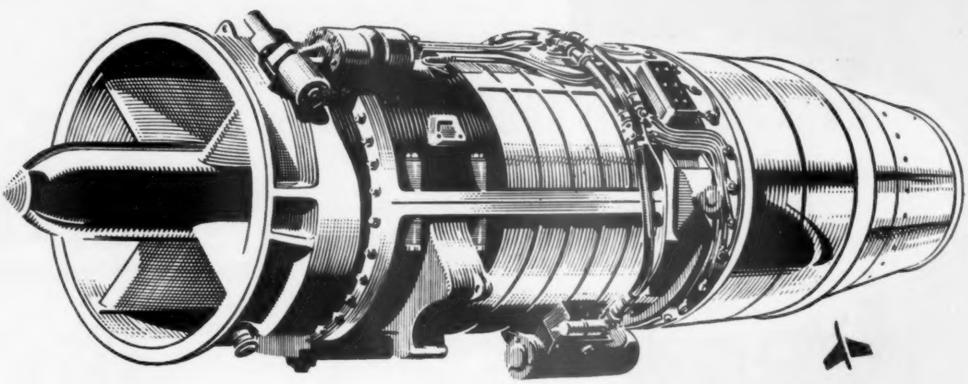

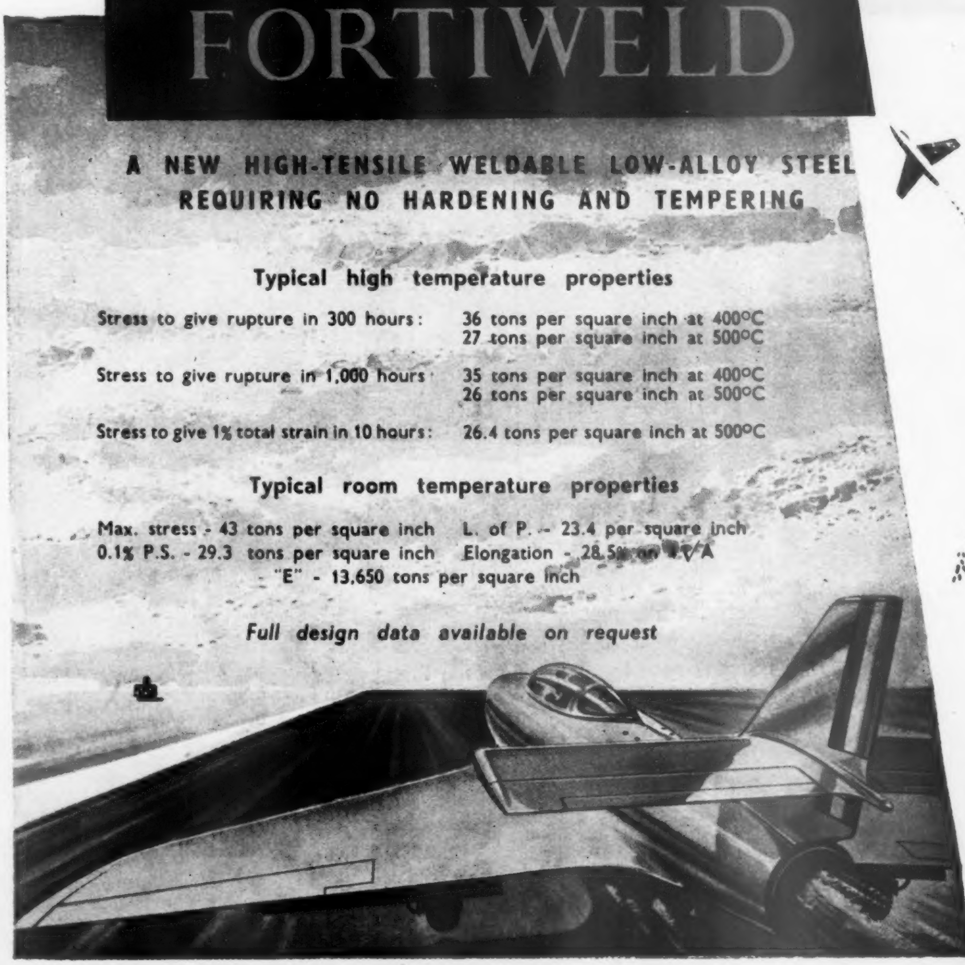

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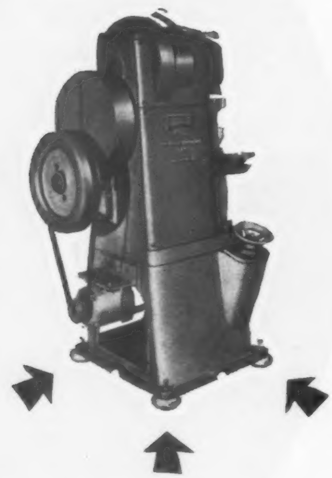

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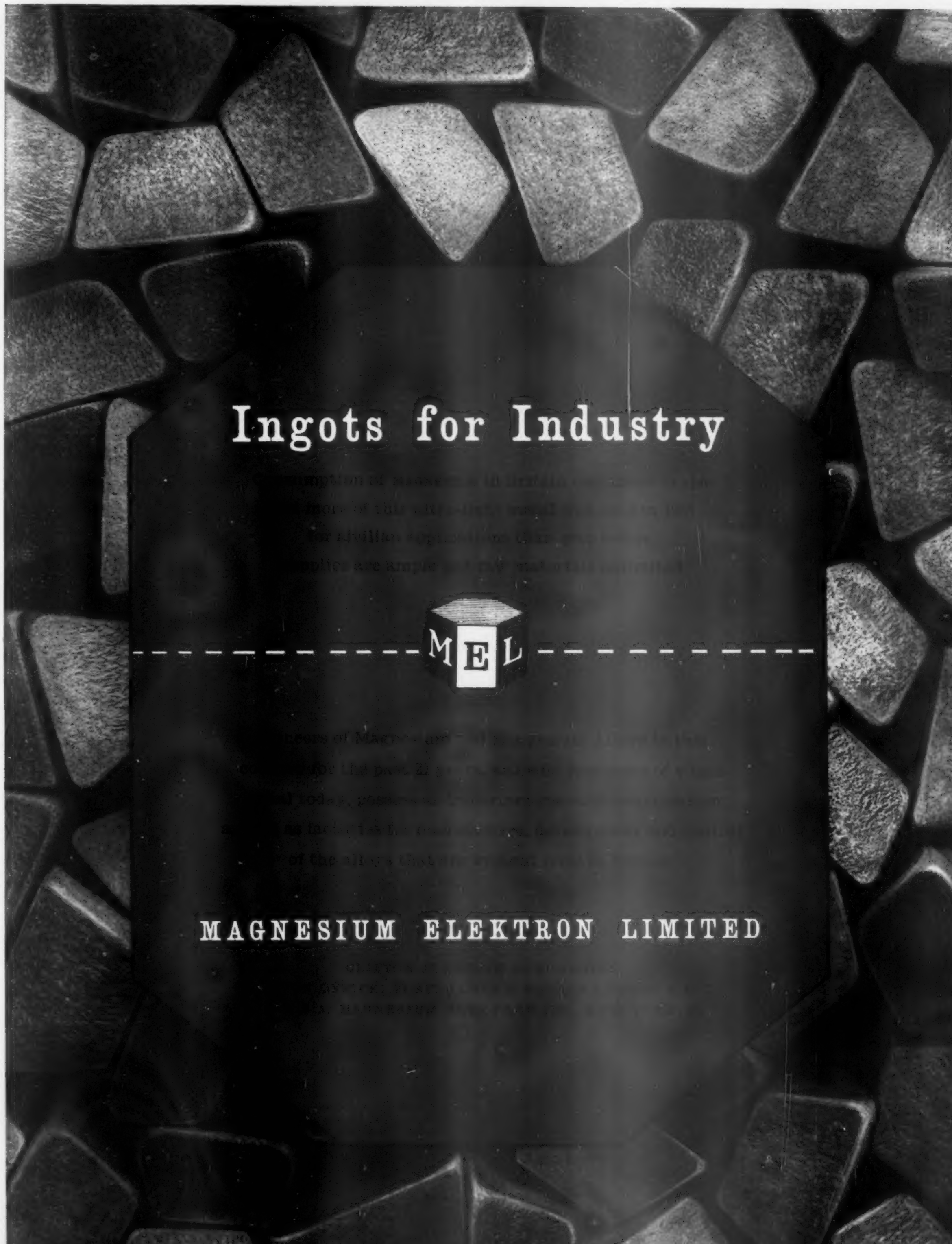
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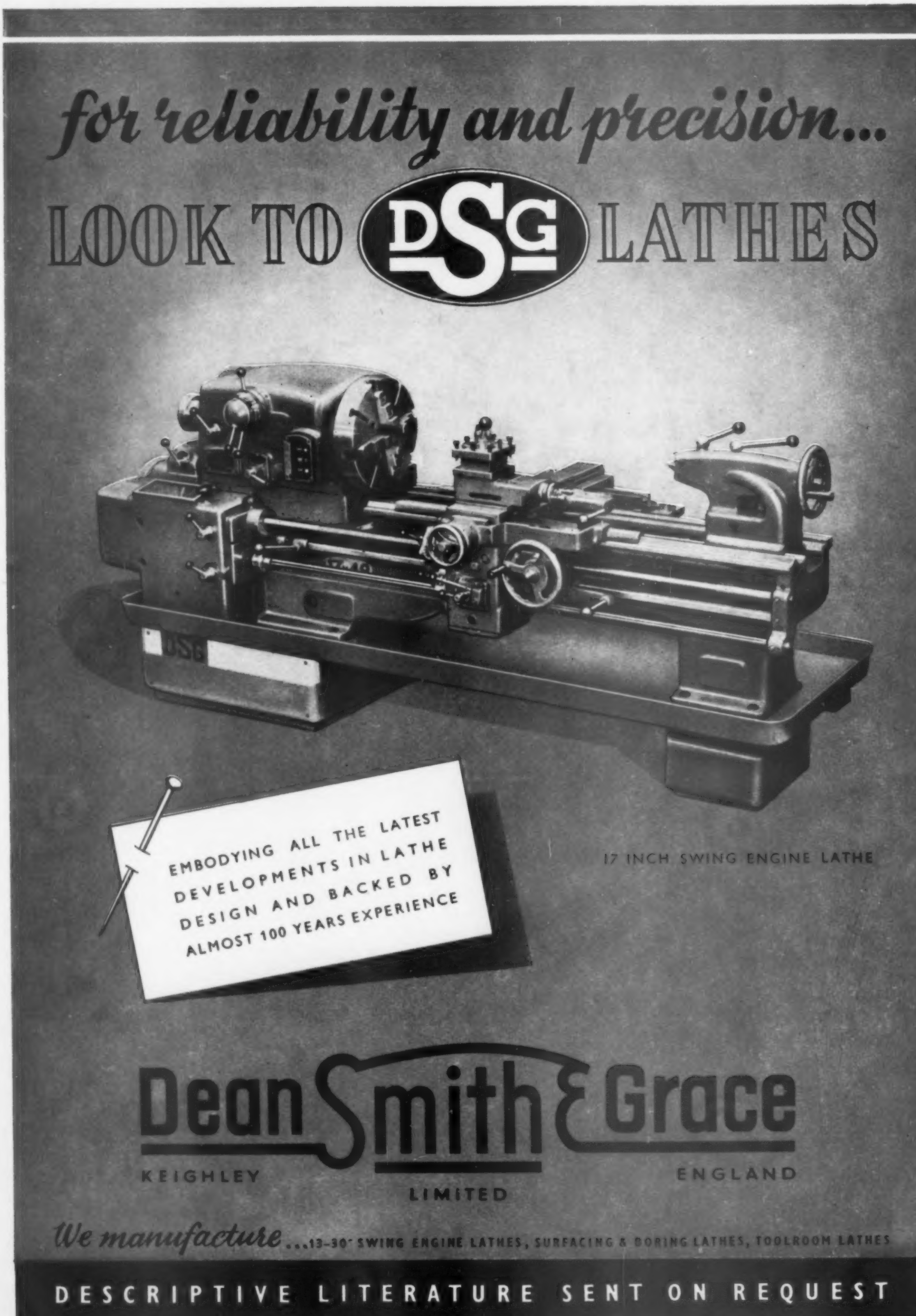
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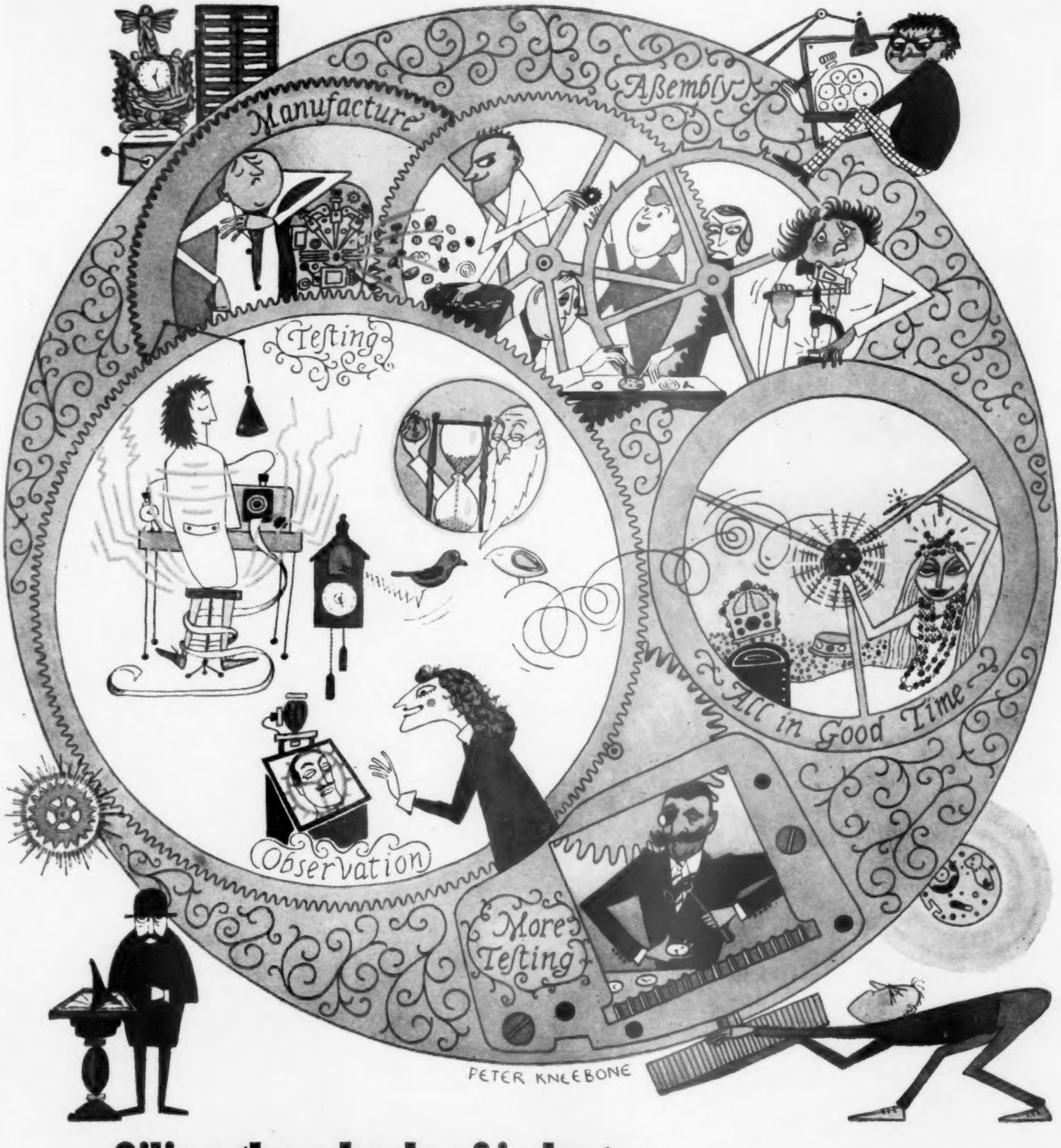

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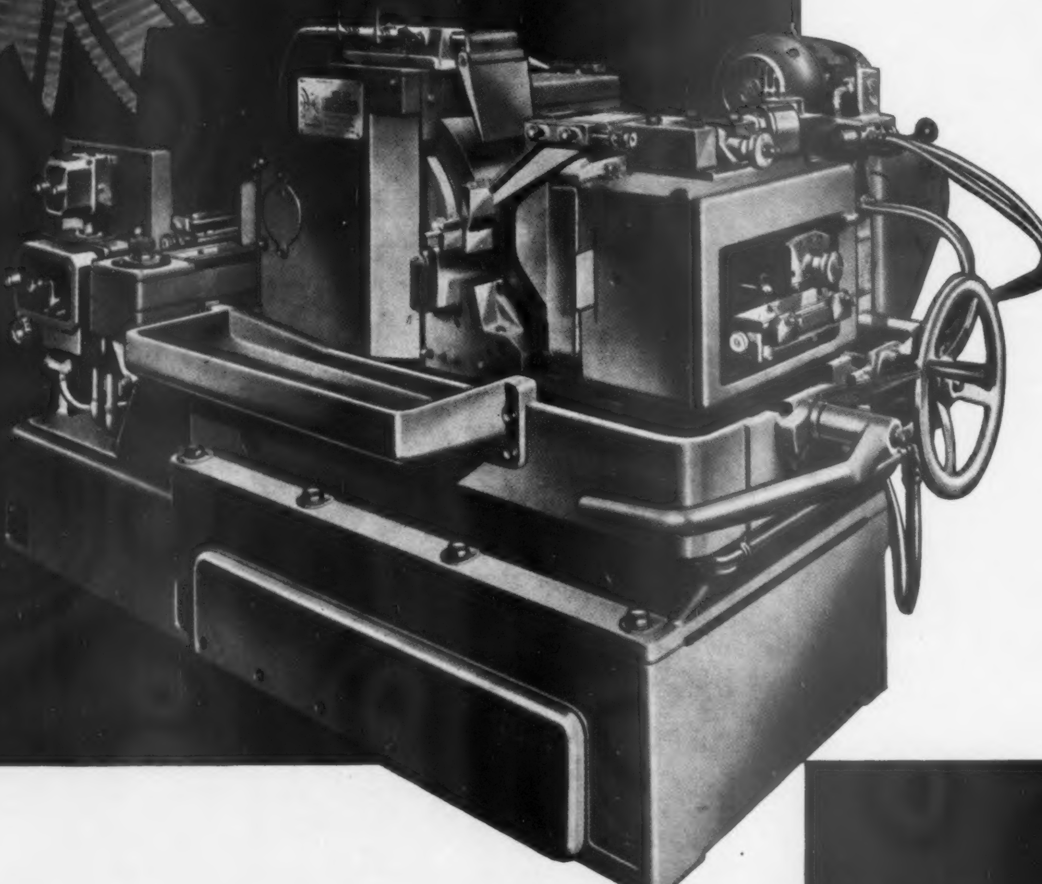

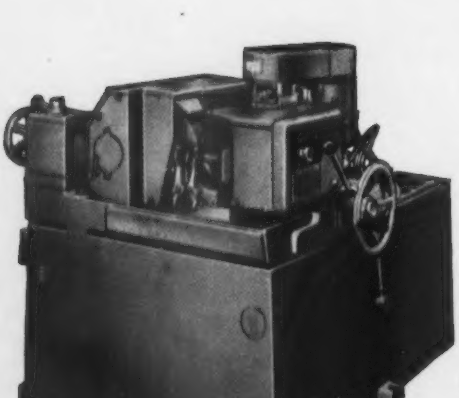

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Will grind all plain cylindrical work from $\frac{1}{8}$" solid bar to 5" tube. In addition a hand-operated plunge grinding mechanism is incorporated for shallow form pieces and shouldered work.

Scrivener No. 1.D Centreless Grinding Machine
A popular machine for centreless grinding small components to the highest standards of accuracy, with a surface finish as fine as 2 micro-inches.

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Arthur Scrivener Limited have been manufacturing centreless grinding machines for nearly 25 years, and now have a range of machines catering for all classes of work from plain production grinding to precision plunge-cut work exemplified in the controlled-cycle machines also shown here.

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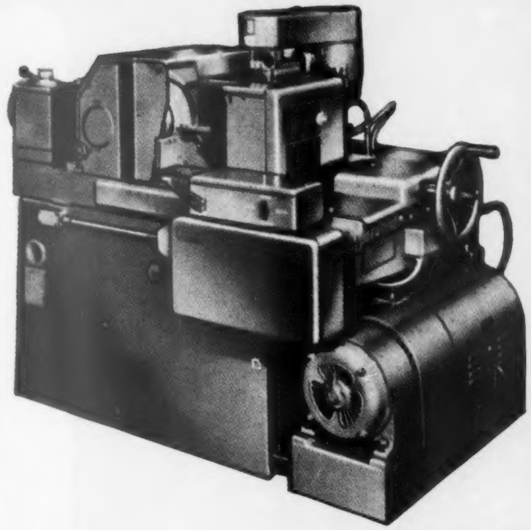
Controlled Cycle plunge grinding makes possible mass production of ground components to limits of $\pm$ 0.00025 on diameter and 0.0001 for roundness — together with a high degree of surface finish.



Scrivener No. 1D Controlled Cycle Machine

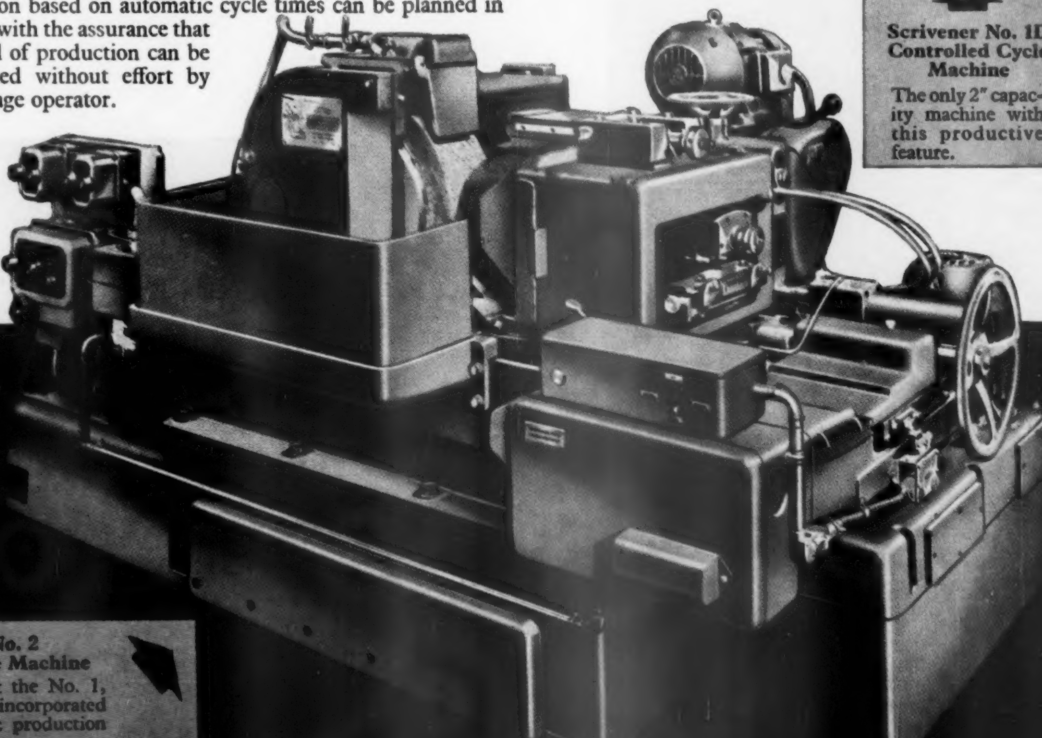
The only 2″ capacity machine with this productive feature.

Automatic Operation

The system depends upon varying automatically the position of a control wheel in relation to the main grinding wheel. Once the work is loaded the control wheel advances whilst the grinding operation is carried out. It then moves back to allow the component to be ejected, finally returning for the next cycle to commence.

Planned Production

Production based on automatic cycle times can be planned in advance with the assurance that this level of production can be maintained without effort by the average operator.



Scrivener No. 2 Controlled Cycle Machine

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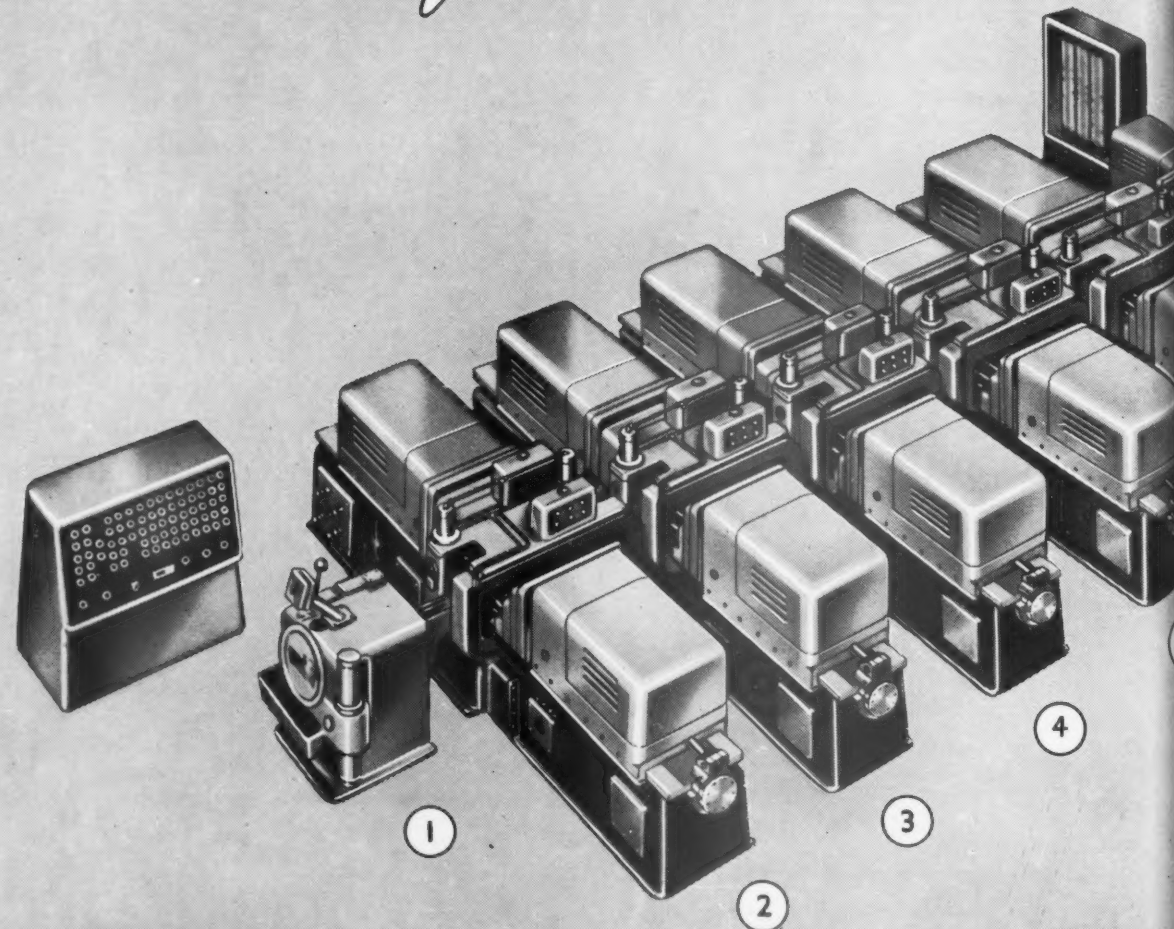
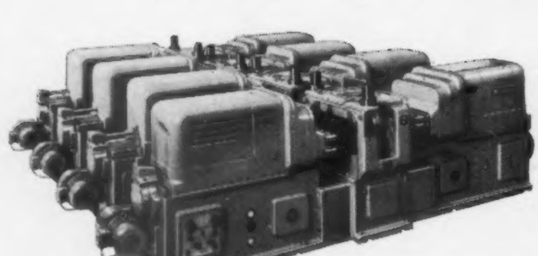
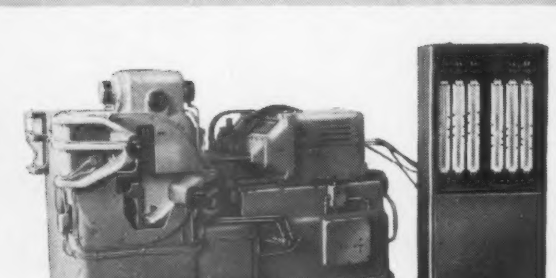
HABERSANG &

Transfer line units



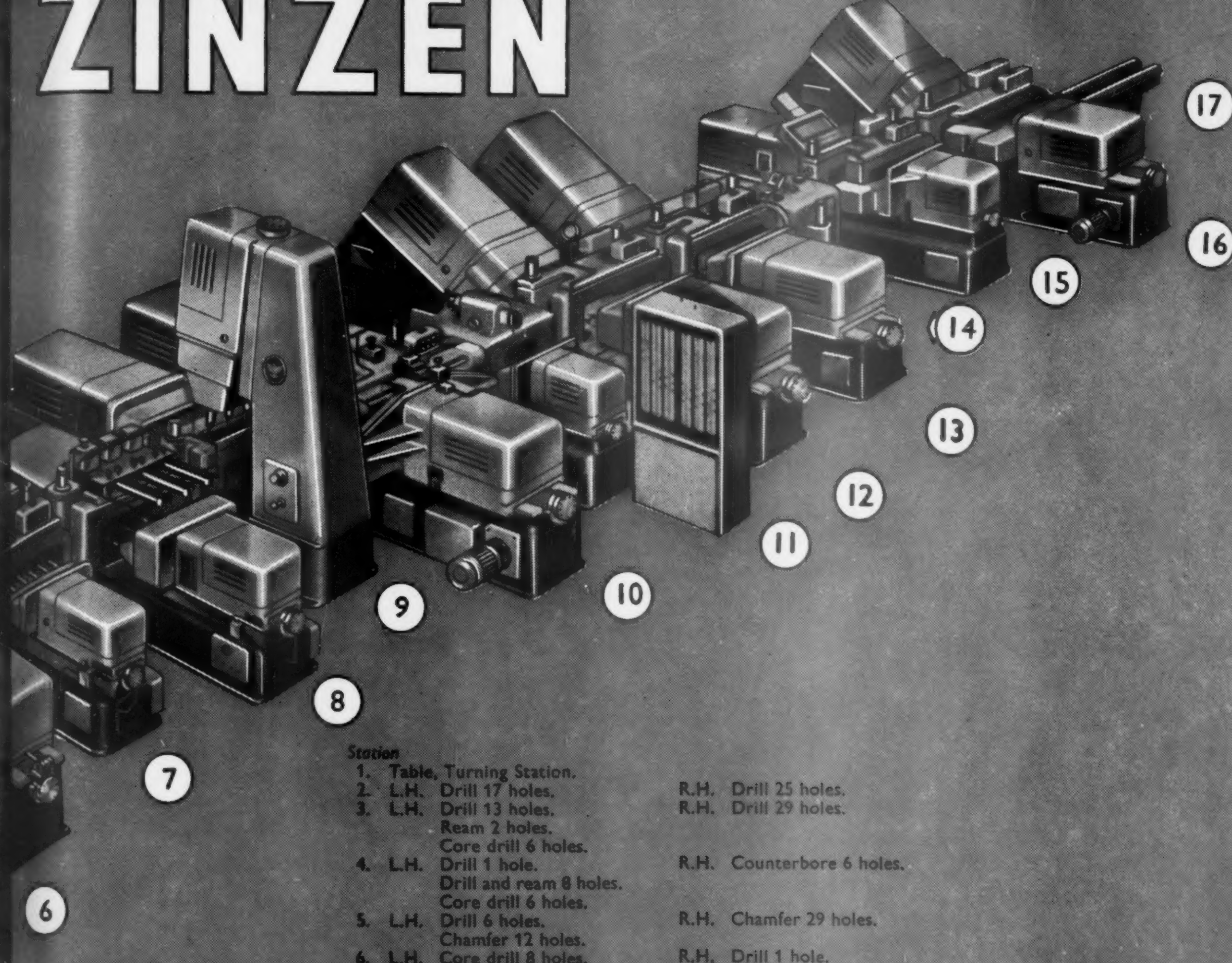


Stations 2, 3, 4 & 5.
Hydraulic units for drilling, reaming and counterboring.



Station 11.
Hydraulic turnover and gauging station.

ZINZEN



Station		
1.	Table, Turning Station.	
2.	L.H. Drill 17 holes.	R.H. Drill 25 holes.
3.	L.H. Drill 13 holes. Ream 2 holes. Core drill 6 holes.	R.H. Drill 29 holes.
4.	L.H. Drill 1 hole. Drill and ream 8 holes. Core drill 6 holes.	R.H. Counterbore 6 holes.
5.	L.H. Drill 6 holes. Chamfer 12 holes.	R.H. Chamfer 29 holes.
6.	L.H. Core drill 8 holes.	R.H. Drill 1 hole. Core drill 6 holes.
7.	L.H. Gauge 28 holes.	R.H. Gauge 48 holes.
8.	L.H. Press in 6 valve seats.	R.H. Tap 12 holes.
9.	L.H. Counterbore 12 holes.	*Vertical.* Drill and chamfer 2 holes.
10.	L.H. Ream 12 holes.	R.H. Core drill and ream 1 hole. Drill and chamfer 2 holes. Gauge 12 tapped holes.
11.	L.H. Turning Station.	R.H. Gauge 12 valve guides.
12.	L.H. Drill 6 tapping holes.	R.H. Drill 8 tapping holes. Counterbore 3 holes.
13.	L.H. Counterbore 6 plug seats.	R.H. Chamfer 11 holes.
14.	Hydraulic Turning Station.	
15.	L.H. Tap 2 holes. Gauge 6 holes.	R.H. Gauge 11 holes.
16.	L.H. Tap 6 plug holes.	R.H. Tap 10 holes.
17.	Unloading Station.	

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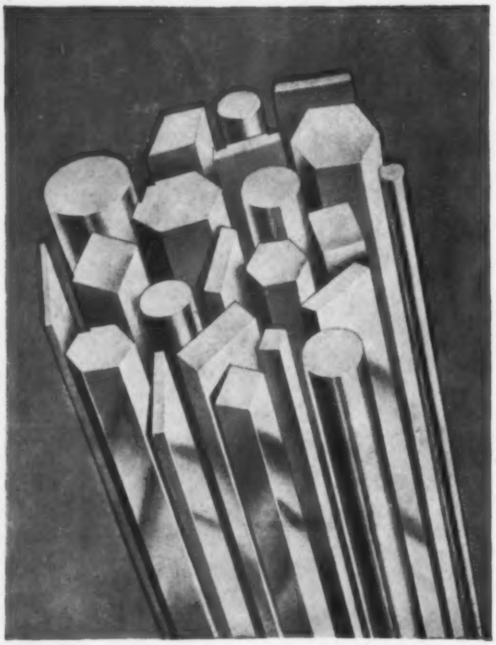

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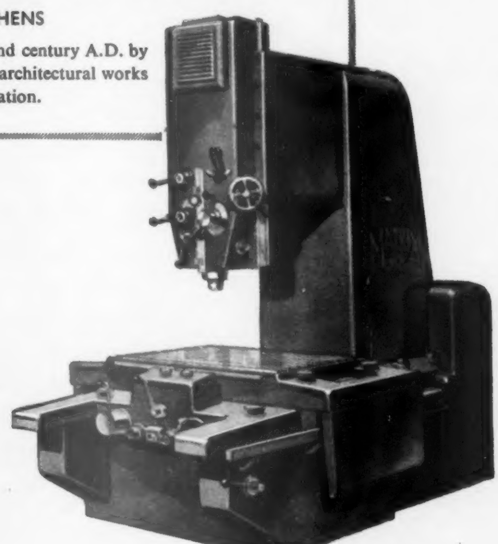

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The Institution of Production Engineers Journal
VOL. 35 NO. 7 JULY, 1956

Official Opening of The Production Exhibition and Conference on Wednesday, 23rd May, 1956

by The Rt. Hon. IAIN MACLEOD,

Minister of Labour and National Service.

THE Minister was welcomed by Mr. E. W. Hancock, M.B.E., President-Elect of the Institution. In his remarks Mr. Hancock said : " I think, Mr. Minister, it should be said that since the last War the Institution of Production Engineers has felt the need for an exhibition devoted to research and development and their application to production and productivity. Because of its constitution this Institution is not able by itself to organise such an exhibition, and we were particularly fortunate when Mr. Woodford, our Secretary, was introduced, by a mutual acquaintance at the Board of Trade, to Mrs. Montgomery, who had conceived the idea that with the resources available to her firm (which has been organising the Building Exhibition for the past 50 or 60 years) they could organise such an exhibition". Mr. Hancock continued: "It is the desire of the Institution of Production Engineers, in partnership with the Andry Montgomery organisation, that this Exhibition shall continue and become a permanent feature in our industrial life. We think it is right from time to time to show the advances which have been made by scientists and by engineers, and particularly production engineers, who are becoming more and more the key men of this country. The Institution of Production Engineers, however, is very much alive to the proper meaning and interpretation of the words 'production' and 'productivity' and realises that the human being is the prime mover, both in creative thought as well as in the final application of ideas. I feel that we must reach through the mist of distortion and misunderstandings now prevalent, and grip firmly the fact that there will always be people, and having grasped this inevitable fact, then face the future human problems of our country in national harmony.

" All of us—employers, management, workers and Government—must have the common objective of the well-being of our country, and by early discussions and consultations agree on policies which make it possible for management and men in the front line — I want to stress that because there is a front line — to win the battle of production for the benefit of our peoples."

In introducing the Minister to the meeting Mr. Hancock concluded:

"We in the Institution of Production Engineers are aware of the great responsibility of the Minister of Labour in relation to the many human problems

associated with new production and developments, and that is why we are so delighted to have the Minister here today, and on your behalf I invite him to be so kind as to open this Exhibition."

Mr. Macleod speaking at the opening of the Exhibition and Conference. With him on the platform is Mrs. M. A. Montgomery and Mr. E. W. Hancock, M.B.E.

The Rt. Hon. Iain Macleod, Minister of Labour and National Service, said: "This is, as you know, the second Production Exhibition, and as the first one was held in 1954 and the third, I see from your programme, is planned to take place in 1958, it seems to be becoming a regular and a very welcome Conference to be held every second year.

"I should like first of all to offer my congratulations to all those who have thought out and planned this Conference ; first of all to the Institution, secondly to the organising firm, and then to the British Productivity Council, to the Trades Union Congress and to many other bodies who have a finger in this pie. As you, Mr. Hancock, said, it is in one way at least rather an unusual Exhibition because it does not exist primarily to display products nor, indeed, to stimulate sales, but rather to show something of the science of productivity and to demonstrate how you in industry are making the best use of manpower, materials and machines. Indeed, it is only quite recently that we have come to think of productivity as a science at all, but a science it is as this Exhibition illustrates.

"We have many problems to tackle in industry today, but then we have solved many problems in the past and no doubt we can meet these and any that the future may bring. We should not conclude from that, however, that time is on our side. Time is against us, and as we move forward and seek for these solutions, I think we should beware of attaching too much importance to words and of confusing slogans with principles. We should beware of thinking that we have done something

when we have only said something, and we must not use words as excuses for inaction or a substitute for thought. You all know that many phrases, for example, 'good human relations', 'work study', 'incentives' and 'automation' have in turn, one by one, tended to dominate our thinking, and I think there is a temptation to believe that here at last is the magic key that is going to unlock the future for us. But progress is not like that. Real progress, both in human relations and in productivity, is much more likely to come from an endless series of small advances rather than from isolated dramatic battles. We cannot shuffle off our responsibilities by setting up a committee, nor can we evade our duties by the use of soothing and glib phrases. I do not believe that we can do an awful lot just by exhortation. It seems to me that example is very much better, and example is the true theme of this Production Exhibition.

"Let me for a moment, in the light of what I have said, look at the factors which affect production. I, naturally, as Minister of Labour, am most interested in people. First of all in any industrial undertaking now, and I would hope always, the major part of its efficiency depends on the ability of its workers, and we can develop natural ability both by systematic training and by education, and in this age of swift technological progress this is a field in which we dare not fail. The trained worker, then, must certainly be given opportunities of using and developing his skill as part of an industrial team, and he, for his part, must contribute first of all the will to work and to do his job efficiently and, secondly and developing naturally from that, a pride in good work. I think these are the four factors — training, opportunity, will to work and pride in work, which are the pillars of everything that we try to do in the field of progress insofar as it affects people.

"Second to people come things. We cannot afford in this country out-of-date equipment. We have to have the newest machines and the most modern techniques, because, as you all know, the struggle for markets all over the world is becoming keener, and we must be able both to hold our old markets and to seize new ones.

"Thirdly, there is the question of policy in the firm. It is not always possible to guarantee complete agreement, but at least from the beginning in joint consultation the problems of development and expansion must be thrashed out. I think it important, too, that management should undertake this, not just because joint consultation is a fashionable phrase, but because they care about the welfare and the future of those who work with and for them.

"Lastly, the Government has its responsibilities as technological development gains momentum. The Government believes in full employment, but it does not believe in frozen employment. There has to be change and there must be a readiness to accept change. That includes, of course, change of jobs. Indeed, only in this way can we maintain the full employment that we have and that we want and mean to keep.

Demand for New Skills

"I do not see the problem of the future as one of labour surplus nor of a shortage of demand. I think that the first and most important thing we have to do is to educate ourselves so that we can all readjust our mental approach to methods of work. Of course, it is true that there will be a gradual change in the composition of the labour force. There will be a demand for new and for higher skills, and this no doubt will mean that while industry may need fewer and fewer unskilled workers, the future will hold greater and greater opportunities for skill. I suppose one day in this country leisure may become a problem ; but we are nowhere near that stage yet. In the past technical progress has always been followed by a reduction in working hours and by an increased standard of living. If we are wise now, and if we are not greedy to mortgage the future, that trend will surely continue. Perhaps it is true to say we think rather too little about these problems. It is not only governments but industry as well which should be studying them now, because the responsibility of industry for its workpeople does not just begin and end with the opening and closing of the factory gates. We have an immense task in front of us and a great deal of hard work to do, but I believe that the road is clearly sign-posted towards a standard of living that is far higher than any that we have dreamed of, and I think that the great merit of this Exhibition is that it helps to chart the way.

"We are a small country and we have limited resources. We have tried to do much — perhaps too much — on rather too slender a base, but at the same time we are a versatile and imaginative people, and we have great reserves of skill as

(*Continued on page* 473)

The Production Exhibition and Conference

Olympia, London

23rd/31st May, 1956

The 16 Papers presented to the Production Conference are being published in the Journal. The June issue contained the Papers presented at the first four sessions, and this issue contains the following:-

SESSION V, 25th MAY

"**Investing in Atomic Energy**" by F. M. Greenlees, B.Sc., M.I.E.E., M.I.Mech.E., A.M.I.C.E.

SESSION VI, 25th MAY

"**Investing in Better Fuel Utilisation**" by L. Clegg, M.B.E., A.M.I.Chem.E., M.Inst.F.

SESSION VII, 25th MAY

"**Investing in Better Factory Design, Construction and Layout**" by Donald Temple Myers, Dip.Arch., Dip. T.P., A.R.I.B.A.

INVESTING IN ATOMIC ENERGY

by F. M. GREENLEES, B.Sc., M.I.E.E., M.I.Mech.E., A.M.I.C.E.

Mr. Greenlees

Mr. Greenlees was educated at Glasgow Academy and Glasgow University, graduating B.Sc. (Engineering) in 1930.

After serving apprenticeships with the McFarlane Engineering Co., Glasgow and the Harland Engineering Co., Alloa, he held posts with the Harland Engineering Co., Glasgow and Alloa, and Bruce Peebles and Co., Ltd., Edinburgh.

He joined the Air Ministry as an Assistant Engineer in 1935, rising to Senior Superintending Mechanical and Electrical Engineer in 1949. Later that year he transferred to the Division of Atomic Energy (Ministry of Supply) as Deputy Chief Engineer. In January, 1951 he became Chief Engineer (Engineering Services) and continued in this post on the formation of the United Kingdom Atomic Energy Authority. In March, 1956, he became Consultant to industrial users of nuclear power in the Industrial Group of the Authority.

I FEEL that to explain how power is derived from atomic energy will be a help to many people who are asking themselves why is this country investing in atomic energy and devoting an appreciable effort to the construction of Nuclear Power Stations.

As atomic energy can be used as a means of raising steam and consequently generating electricity, it can therefore take the place of coal or oil in the production of power. Similarly, the heat generated in an atomic reactor can be converted into motive power and hence we have the possibility of atomic energy taking the place of marine boilers and possibly, ultimately, of the internal combustion engines in some applications.

It is necessary, in order to appreciate the many applications of atomic energy, to visualise the nuclear reactor purely as a furnace in which heat is generated, and to understand that the heat extracted from the nuclear reactor is not limited by the temperature of nuclear fission, but by the temperature at which engineering and metallurgical considerations dictate that the fuel elements can be safely operated.

There are large amounts of heat available from the reactor which must then be translated into power by a fairly normal thermo-dynamic cycle, and if electricity is to be generated by the use of conventional type turbines and generators.

The Atomic Energy Authority is already designing and constructing reactors which will be capable of producing electricity, and at Calder Hall in Cumberland we are constructing reactors which are a direct development of the earlier reactors which were built for experimental purposes at Harwell and for production purposes at Windscale, in Cumberland.

In addition, we have under construction at Dounreay in Caithness one of the more advanced types of reactor, which is in itself of very small dimensions but is also capable of generating appreciable quantities of electrical energy.

What a Nuclear Reactor is Like

In order that you may appreciate first of all what these reactors are really like, it is as well to commence by studying a reactor such as those being built at Calder, and Fig. 1 illustrates the basic conception. Here we have a reactor core or block built up of numerous graphite bricks into a cube with parallel holes or channels into which the fuel elements are charged, and you will see that control rods and shut-off rods can be inserted into or pulled out of the reactor block as required.

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The next illustration (Fig. 2) shows how this basic principle is built into a Calder type reactor.

In this case, the graphite block is built into a cylindrical vessel about 40 ft. in diameter by 60 ft. high and the fuel elements are charged into and discharged out of the reactor from above, thus both the fuel elements and control rods are in vertical channels. The reactor is cooled by gas under pressure and in this case carbon dioxide is used and circulated by four large motor driven blowers, the hot gases being passed through four independent heat exchangers where the heat is transferred into the feed water and steam is generated.

As a complete contrast, Fig. 3, shows the general arrangement of the Dounreay reactor in its surrounding steel sphere. Here we have a very small core of fuel surrounded by a blanket of fertile material all in a small steel vessel only a few feet in diameter. In this case, the reactor is cooled by circulating liquid metal and both primary and secondary heat exchangers are used so as to eliminate the presence of radio-activity in the secondary heat exchangers where the heat obtained from the reactor core is transferred to the water cycle to generate steam.

One has to appreciate that this is a reactor of very small dimensions in a large steel sphere, built in this manner purely to eliminate the dispersal of gaseous bi-products should these be accidentally liberated, which is a precaution taken to minimise the possibility of any hazard to personnel, as this is a highly advanced experimental reactor.

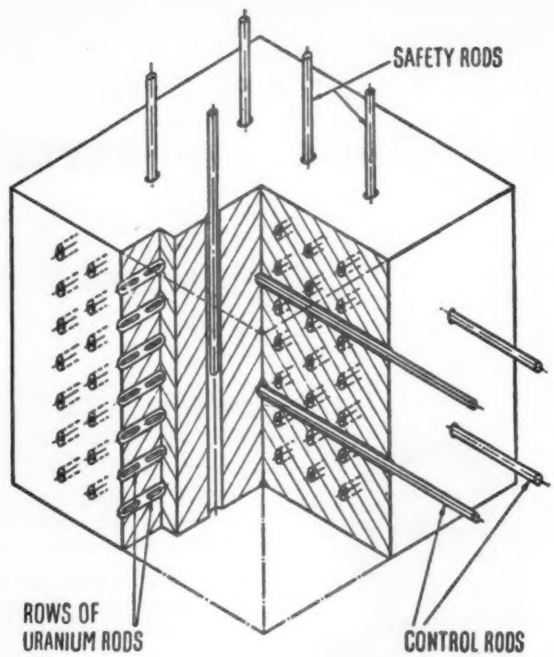


Fig. 1. Typical arrangement of a reactor core.

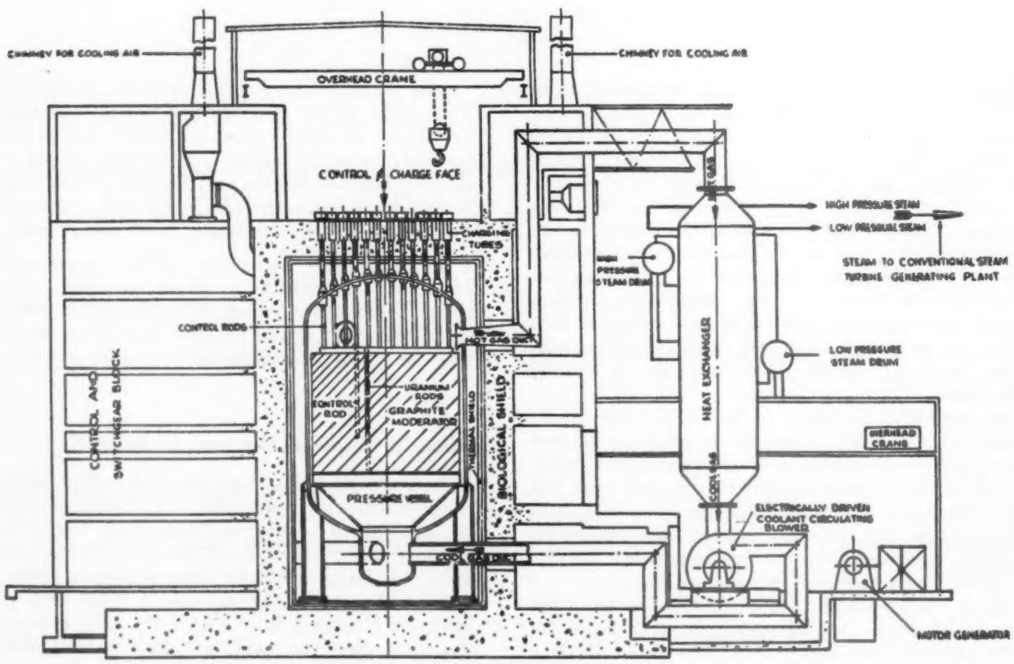
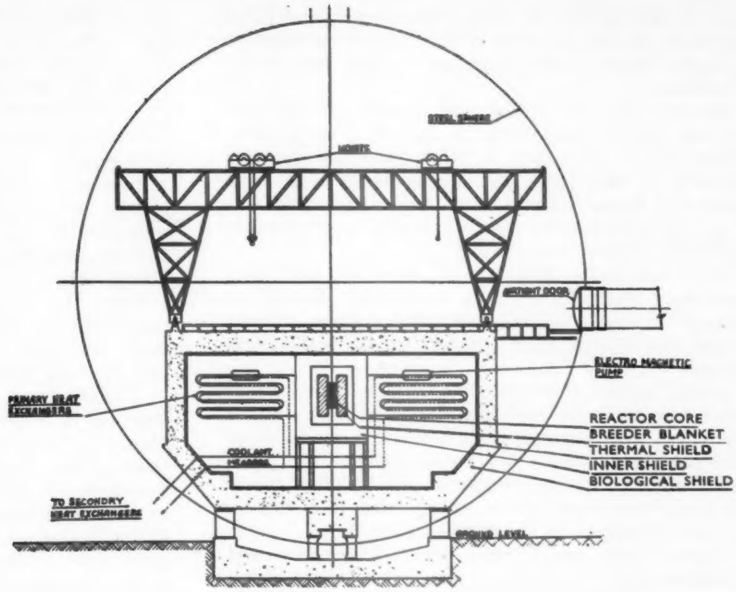


Fig. 2. Diagrammatic arrangement of the Calder type reactor.

Fig. 3



ARRANGEMENT OF THE DOUNREAY FAST REACTOR SPHERE

From these diagrams it will be seen that the one prime consideration in any reactor is the fuel and the way in which it is prepared, but also of importance is the coolant, be it a gas or a liquid, which extracts the heat from the reactor core and enables us to maintain the temperature of the fuel within controlled limits.

In addition, we have in some reactors what is known as a moderator and it is used to control the manner in which the nuclear reaction is permitted to take place.

In some types of reactor the coolant is also the moderator and is being continually changed by being circulated round the coolant circuit.

Some Basic Principles

Attached to this Paper is a simple Appendix* which sets out the basic principles of nuclear fission and from this we see that the normal fuel is natural uranium, which is made up of 0.7 per cent of the fissionable Uranium 235 and 99.3 per cent of Uranium 238 which is not fissionable. From this Appendix we also see that the chain reaction using natural uranium gives us Plutonium 239. This is also fissionable and can therefore be used as a fuel.

Just as Plutonium is made by irradiation of Uranium 238, Uranium 233 can be made by irradiation of the next lower element in the atomic scale, Thorium 232. Thus we have three fuels which are fissionable, Uranium 233, Uranium 235 and Plutonium 239, the first and last being made by converting the fertile elements Thorium 232 and Uranium 238. However, Uranium 235 is the only fissionable material found in nature.

* Page 434.

Now we come to some of the possible coolants which may be used and we have first of all the simple gases such as hydrogen, helium and nitrogen and compound gases such as carbon dioxide, all of which have their own particular advantages and disadvantages.

Observing from the Appendix that an average of 2 to 3 neutrons are given off by each fission of a nucleus, it is desirable to use a coolant which has a reasonably low ability to capture neutrons, as otherwise the sudden disappearance from the reactor core of a coolant which had a high capture ability would immediately increase the neutron availability; and consequently the use of the latter type of coolant makes the reactor inherently dangerous.

Various gases obviously have different thermal conductivities but they also require individual consideration in regard to their effect on the materials from which the reactor and its fuel elements are constructed.

Secondly, we have the liquid coolant of which the most obvious is light water i.e., reasonably pure drinking water, and heavy water which is a compound of oxygen with the heavy isotope of hydrogen.

The thermal conductivity of water is, of course, well-known, but light water and heavy water have different abilities for neutron capture; therefore, while the light water cooled reactor is inherently dangerous under certain conditions, the heavy water reactor is intrinsically safe.

Alternatively there is a range of liquid metal coolants such as sodium, potassium, mercury or their alloys which could be operated at higher temperatures than water which has to be pressurised to perhaps

1000 lb. per square inch to prevent it vapourising; therefore, the liquid metal coolant has the advantage of higher heat transfer rates for a given amount in circulation.

Certain reactors which are known as thermal reactors would use what is called a moderator, which could be either a solid material such as graphite or beryllium, but alternatively both light water and heavy water can be used as a moderator as well as a coolant, in which cases the reactor vessel is virtually turned into a tank.

Some reactors would not however use any moderator and the neutrons would be allowed to operate at their initial velocities without being slowed down; and these reactors are known as fast reactors.

It will be seen therefore that with the various fuel cycles which can be used and the alternative designs of reactors which are possible, both with and without moderators and with a variety of coolants, there are a multitude of design prospects which will increase still further as more advanced materials of construction are developed by the metallurgists.

There is no doubt that design engineers and physicists will strive to extract more and more of the heat given off by nuclear fission. They will do this by considering the suitability of various materials and the relative conditions of fuel and coolant which will enable them to operate their fuel elements at higher and higher temperatures.

Types of Reactors likely to be Seriously Considered

Within the United Kingdom Atomic Energy Authority, we are certain that provided appropriate care is taken in the design and that appropriate safeguards are applied in their operation, several types of reactor are practical propositions and could eventually be built and operated as sources of heat and power.

It is not my intention to try and explain in this Paper the technicalities involved in the design of such reactors, as it is obviously a large subject in itself; nor is it necessary to go into the detailed engineering problems of construction.

Quite an appreciable amount, however, has already been published on the probable types of reactor which are likely to be given serious consideration.

To assist any of you who may be unfamiliar with the fundamental principles of a nuclear reactor you should turn, in the first instance, to the Appendix, from which it will be clear :—

1. An atomic nucleus is split in a reactor when struck by a free neutron from an atom of fissile material, such as Uranium 235 and the nucleus then splits into smaller nuclei of lighter elements giving off more free neutrons and also heat.

2. A chain reaction occurs when there are several free neutrons over and above those lost or absorbed in the reactor to continue the process of splitting the nuclei of fissile atoms. The neutron availability will, of course, depend upon the type of fuel used and the amount of neutron absorbing non-fissile material present in the reactor; observing that neutron loss also occurs by dissipation from the outside surfaces of the reactor core.

Now in some types of reactors the neutrons are deliberately slowed down to what are called "thermal" velocities to improve the chance of further fission and this is done by what is known as a moderator. In intermediate or fast fission reactors, the moderator may be reduced or dispensed with altogether.

Let us for a moment consider the reactors which have already been or are being built in this country. Both the early experimental reactors at Harwell and the two production reactors or piles at Windscale in Cumberland, are air-cooled and have graphite matrices into which the fuel is charged, the graphite acting in each case as a moderator. None of these reactors was built for power production and have, therefore, no facilities for utilising the heat released in nuclear fission, but the second Harwell reactor had a heat exchanger fitted in 1948 which provides some four million British Thermal Units per hour of heat for space heating. This, of course, is only a fraction of the available heat and was purely experimental.

At present we have under construction at Calder the first major power producing reactors. These, as I have said, are also graphite-moderated but are gas-cooled, using carbon-dioxide under pressure as the coolant. The heat is extracted from the carbon-dioxide by four large gas to water and steam heat exchangers and power will be developed by conventional type turbines and generators.

Now let me express, in approximate terms, some of the possible outputs of heat and power of reactors worthy of consideration :

(a) Taking first of all the graphite-moderated gas-cooled reactor similar in type to our Calder Hall reactors (see Fig. 4), it may have a core built inside a pressure vessel of about 40 ft. in diameter and may hold some 110 tons of fuel in one charge. Assuming a heat rating of 1 to 2 megawatts per ton of fuel, we may expect to extract about 750 million B.T.U.'s/hour of heat at an upper temperature of 660°F. So allowing for plant thermal efficiencies we may expect to generate 45 megawatts of electrical power from such a reactor.

To some of you this gross electrical power for one reactor may seem small compared with modern conventional power station capacities, but when one realises that 45 megawatts is one-third of the power required by the city of Birmingham, the figure begins to get into perspective. In other words you may consider the cost of three 200,000 lb. per hour water tube boilers and their associated plant, two of them normally in use, against one such reactor in order to draw a comparison which is more readily understood.

Alternatively a graphite moderated reactor could be liquid metal cooled and this design

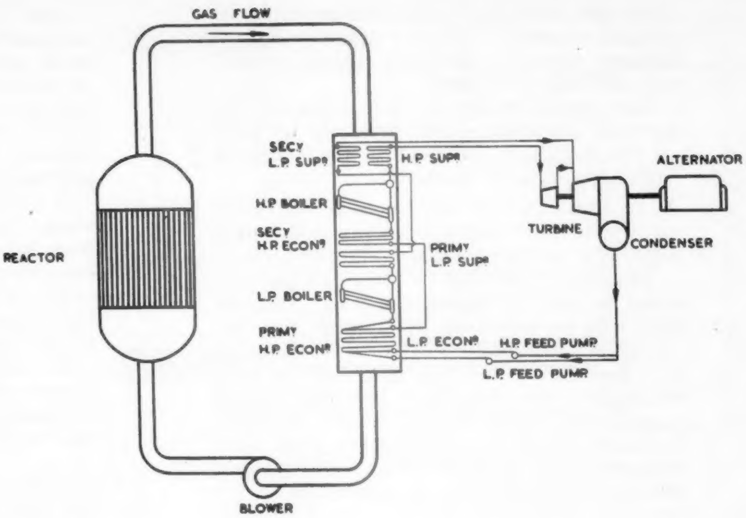


Fig. 4.

DIAGRAMMATIC ARRANGEMENT OF SIMPLE DOUBLE PRESSURE STEAM CYCLE FOR USE WITH A GAS COOLED PILE.

has possibilities because of the higher coolant temperatures to which one may go, which may be of the order of 900 °F.

In this case the reactor would have a core possibly 25 ft. in diameter and would hold say 100 tons of fuel, Assuming a heat rating of about 5 megawatts per ton of fuel, we may expect to extract about 1700 million B.T.U.'s/hour of heat at the temperature I have given. So allowing again for plant thermal efficiencies we may expect to generate over 100 megawatts of electrical power from such a reactor. This design introduces appreciable engineering and metallurgical problems in pumping liquid metal and in the compatibility of materials.

(b) Next let us consider the possibilities of a reactor moderated and cooled by heavy water (see Fig. 5) which would have a core diameter of about 8 ft. This core situated in a tank about 10 ft. diameter would hold say 10 to 12 tons of fuel and might have a rating of 4 to 6 megawatts per ton. We may expect to extract about 250 million B.T.U's/hour at temperatures up to 525 °F. provided the coolant system, i.e., the heavy water circulating system, is pressurised to 1000 lb. per square inch.

I should say perhaps that this heavy water is not something for drinking at a few pence per thousand gallons, but is as I have mentioned a compound of oxygen with a heavy isotope of hydrogen and may cost at least £250 a gallon.

Allowing again for plant efficiencies, we might expect 15 megawatts of generated electrical power from such a reactor, but as this is a comparatively small power output

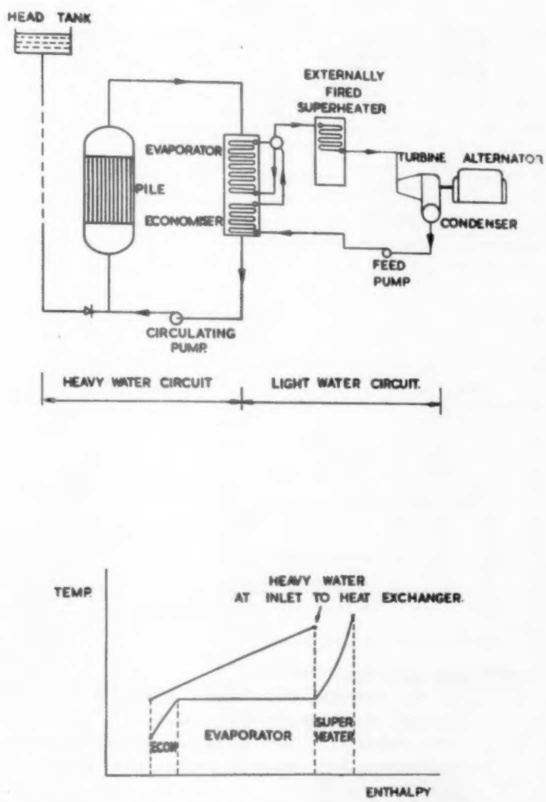


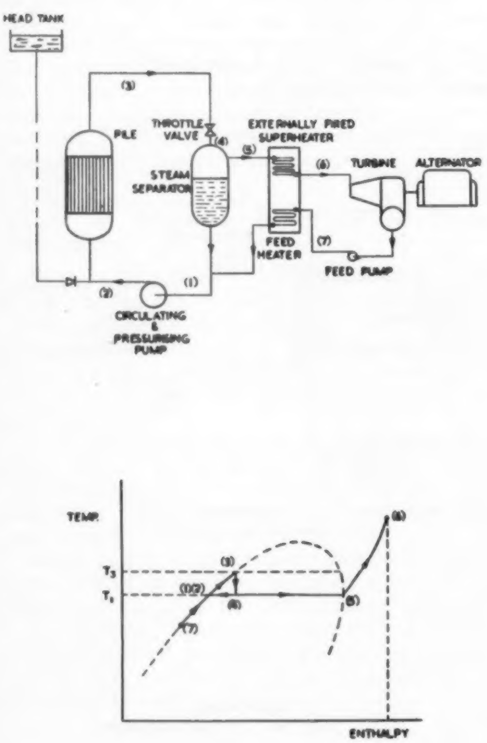
Fig. 5. Diagrammatic arrangement for a heavy water cooled reactor.

these days, several of these reactors could be grouped together to give the desired electrical capacity, observing that each of these reactors is itself reasonably small.

The maximum size of such a reactor, for practical purposes, would probably be fixed by the limitations inherent in the design of large high pressure vessels.

(c) As an alternative we could consider a reactor using light water, that is to say reasonably pure H_2O, both as the moderator and the coolant.

This reactor can also be built in a pressure vessel to prevent boiling the water and the heat can be extracted by normal heat exchangers. Alternatively it could be designed as a flash boiler and thus eliminate the heat exchangers (see Fig. 6). The light water reactor core would be around 10 to 12 ft. in diameter built in a vessel of, say, 12 to 14 ft. diameter and being taller than the heavy water reactor would hold about 50 tons of fuel.



TYPICAL CONDITIONS :-
PILE INLET TEMPERATURE, $T_2 = T_1$ = 205°C (401°F)
PILE OUTLET TEMPERATURE, T_3 = 231°C (448°F)
STEAM PRESSURE 235 p.s.i.g
PILE PRESSURE (> SAT'N. PRESSURE CORRESPONDING TO T_3) 535 p.s.i.g.

Fig. 6. Diagrammatic arrangement for a light water cooled reactor.

Again assuming a heat rating of 4 to 6 megawatts per ton and allowing for the vessel to be pressurised to 1000 lb. per square inch, we might extract about 1000 million B.T.U.'s/hour from the reactor at the same temperature 525°F. This, allowing again for plant efficiencies, represents about 60 megawatts of generated electrical power.

It may be a little misleading that the heat would be extracted at a lower temperature from both the heavy water and light water reactors than from a gas-cooled reactor, but owing to the higher circulation possible with a liquid coolant the turbine steam conditions may be very similar in each case.

In addition, it may be desirable from an overall efficiency point of view to instal a separately-fired superheater to improve the steam conditions.

(d) Now if we consider a fast fission reactor without any moderator and cooled by liquid metal such as lead, mercury, sodium or sodium potassium alloy, it is estimated that such a reactor can breed more fissile material than it consumes. We can then work with a core size of only some 2 or 3 ft. diameter, in a vessel only slightly larger surrounded by a uranium neutron reflector contained in a still larger vessel (see Fig. 7).

As I mentioned previously our new reactor at Dounreay in Caithness is being built on these lines.

A fuel richer in fissile material than natural uranium would be necessary, and heat ratings of 70—100 megawatts per ton of fuel might be possible. Assuming the size I have given would hold about 2000 lb. of fuel, and observing that the heat transfer properties of these liquid metal coolants will permit the extraction of considerably more heat per unit mass of fuel, we might expect to extract around 200 million B.T.U.'s/hour at an upper temperature of 660°F. or even higher.

We can then obtain about 15 megawatts of generated electrical power from the minimum size of reactor.

(e) Lastly, there is the homogeneous type of reactor in which the fuel is in solution or in suspension in the liquid coolant and the entire hot solution is pumped round through the primary heat exchangers and thus permits still more efficient heat extraction (see Fig. 8).

With this type of reactor the designer is not restricted in fixing his upper temperature by the metallurgical problems of providing canned fuel elements as in the first four types of reactors, and chemical processing of the fuel can be carried on continuously in a by-pass system. Large savings in chemical plant, fuel element preparation shops and de-canning ponds can be achieved in this design. This type of reactor could be produced in various sizes and might have a rating of 15 to 20

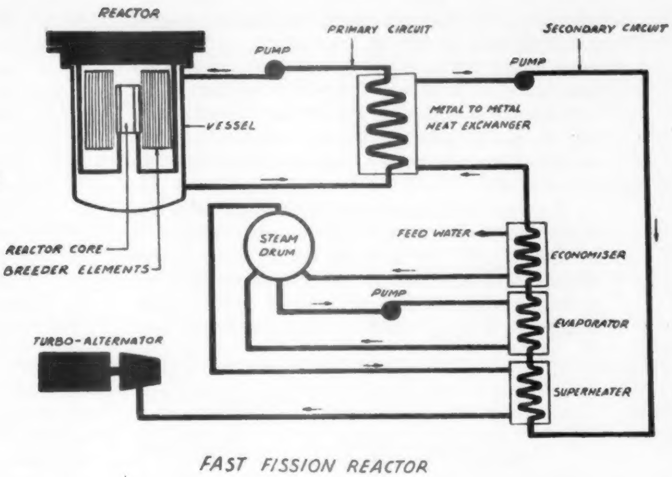


Fig. 7. Diagrammatic arrangement for a fast fission reactor.

megawatts per ton of basic fuel and consequently we might expect to extract some 50 to 70 million B.T.U's/hour per ton of fuel in the cycle.

The heat in this case is likely to be extracted at very high temperatures only limited by metallurgical considerations of the circulating system materials, and possibly in the region of 900°F. in the first instance. It should be appreciated, however, that the electrical power obtained from such a reactor will vary with the tonnage of fuel in use and only the normal engineering limitations to the size of the plant will apply.

A reasonable estimated output would be 60 megawatts and it may be interesting to note in addition that one American paper has put the fuel burn up of this type of reactor as low as .002 lb. per megawatt day and this is probably a fair estimate.

Perhaps it would be helpful for the purposes of rough comparison if I sum up these reactor performances and assess them in terms of coal and oil. Bearing in mind that it takes nearly 470 tons of coal or 260 tons of oil per annum to maintain a heat output of a million B.T.U.'s/hour and 4,500 tons of coal or 2,500 tons of oil per annum per megawatt of electricity generated assuming a 30 per cent efficiency, the anticipated outputs of the five types and sizes of reactor I have mentioned would come out very roughly as follows :—

The graphite moderated gas-cooled reactor with 110 tons of fuel and an electrical output of 45 megawatts would have a fuel burn-up of about 160 lb. per annum against an equivalent yearly consumption of 200,000 tons of coal or 110,000 tons of oil.

A graphite moderated liquid metal cooled reactor with 100 tons of fuel and an electrical output of 100 megawatts would have a fuel burn-up of about 400 lb. per annum against an equivalent yearly consumption of 460,000 tons of coal or 250,000 tons of oil.

The heavy water reactor with 10 to 12 tons of fuel and an electrical output of 15 megawatts would have a fuel burn-up of about

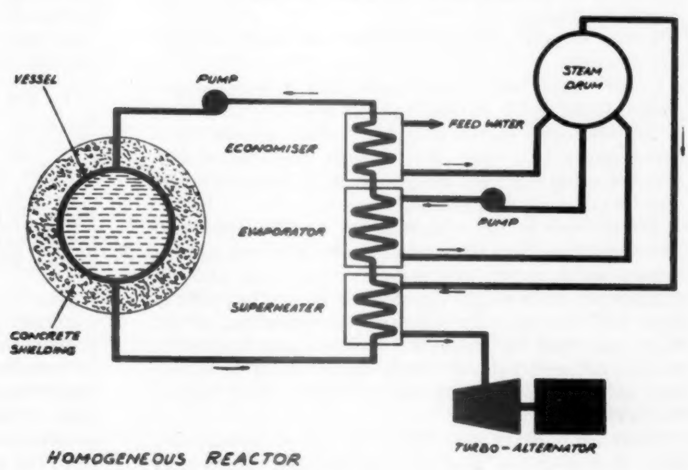


Fig. 8. Diagrammatic arrangement for a homogeneous type reactor.

56 lb. per annum against an equivalent yearly consumption of 67,500 tons of coal or 36,500 tons of oil. The light water reactor with 50 tons of fuel and an electrical output of 60 megawatts would have a fuel burn-up of about 230 lb. per annum against an equivalent yearly consumption of 275,000 tons of coal or 150,000 tons of oil.

The fast fission reactor with only 2000 lb. of fuel in the core and an electrical output of 15 megawatts would have a fuel burn-up of about 48 lb per annum without allowance for breeding against an equivalent yearly consumption of 67,500 tons of coal or 36,500 tons of oil, and the homogeneous reactor with say 10 tons of basic fuel and an electrical output of 60 megawatts would have a fuel burn-up of about 156 lb. per annum against an equivalent yearly consumption of 275,000 tons of coal or 150,000 tons of oil.

In other words, from each ton of uranium fuel charge in the larger power reactors I have mentioned, we may have an average yearly burn-up rate of 3 lb. which would be producing the equivalent heat of 4,000 tons of coal or 2,160 tons of oil per annum.

These estimated figures can be tabulated for quick reference as follows :—

Type of Reactor	Approx. wt. of fuel charge	Elec. power rating M.W.	Burn-up in lb. p.a.	Equivalent annual consumption in tons of coal or oil *coal*	*oil*	Equivalent process steam production in lb. hour at 100 p.s.i.	Equivalent available Shaft Horse Power (B.H.P.)
Graphite-moderated gas-cooled	110 tons	45 M.W.	160 lb.	200,000	110,000	575,000	58,000
Liquid Metal Cooled Graphite Moderated	100 tons	100 M.W.	400 lb.	460,000	250,000	1,300,000	130,000
Heavy water reactor	10-12 tons	15 M.W.	56 lb.	67,500	36,500	200,000	19,000
Light water reactor	50 tons	60 M.W.	230 lb.	275,000	150,000	775,000	77,000
Fast fission reactor	2000 lb.	15 M.W.	48 lb.	67,500	36,500	150,000	19,000
Homogeneous reactor	10 tons	60 M.W.	156 lb.	275,000	150,000	525,000	77,000

Now admittedly uranium is a processed fuel which is expensive but the country's resources of coal are limited and the cost of mining and delivering it are constantly rising.

Many of you will believe that this trend is likely to continue.

Some people may even claim that it is no longer desirable to burn coal purely for its heat of combustion as it is obviously such a valuable product for chemical processing. It is therefore of great importance that ways of using the heat from nuclear fission should be developed along all practical lines.

Having made these statements on the heat and power expectations from various reactors and having drawn some rough ccmparisons with coal and oil consumptions, it would be only fair to say that capital costs will, in the early stages of development, prove high, but will be reduced in time when engineers and metallurgists develop new materials of construction so that the reactors can be operated at higher temperatures.

Heat exchangers and other reactor auxiliaries are of course essential, and for the present one would tend to use fairly conventional generating plant. It is, of course, necessary to provide biological shielding to protect the operating personnel against the harmful effects of radiations from the reactor core and this represents an appreciable proportion of the capital cost.

In the first nuclear power station at Calder Hall we hope, however, to generate electrical power at about ¾d. per unit and in the first of the new atomic stations to be built by the Central Electricity Authority under the recent Government White Paper, it seems that it may be possible to generate power at a cost of 0.6d. per unit allowing due credit, as fuel, for the plutonium produced.

Bearing in mind that the heat extracted need not necessarily be converted into electrical energy, process steam, raising or space heating could also be undertaken on a very large scale at a running cost of about 3s. 8d. per thousand lb. of steam, including the cost of electricity made available for the reactor auxiliaries, either from a separate supply or generated from the reactor heat output itself.

Problem of Electricity Generation, Process Steam Raising and Production of Motive Power

Having considered some six alternative approaches to reactor design and their possible performances, it may be useful to consider for a moment how each of these designs would apply to the production of electricity, steam (or heat) and motive power.

If any reactor is to work at all there is a minimum amount of fuel required for the reactor to become divergent, that is to say, for the chain raction to continue.

This of course depends upon the enrichment of the fuel, observing that natural uranium, as mined, has only 0.7 per cent of the fissionable isotope Uranium 235. Obviously fuels richer in Uranium 235 or Plutonium 239 and also Uranium 233, as opposed to the non-fissile isotopes Uranium 238 and Thorium 232, will maintain a chain reaction with smaller quantities in the core and consequently reduce the overall size of the reactor. The richer fuels are however going to prove more expensive and in design one would, therefore, have to strike an economic compromise between capital construction costs and running costs.

For certain purposes, particularly in the production of motive power, space considerations may be over-riding and therefore smaller reactors with richer fuels may be used.

Within this compromise it is possible to group those reactors which are likely to be static and those which could in certain circumstances be transportable, for example in the form of marine propulsion.

Normally all the types of reactors I have described fall into the first category and one would visualise for power generation gas or liquid metal-cooled graphite-moderated reactors in the first instance, (see Fig. 2), followed possibly later on by fast fission or homogeneous reactors, although heavy water and light water reactors would also have their uses.

The fast fission reactors which have the ability to breed more fissile material than they consume are to some extent complementary to the large graphite-moderated reactors, as they can use as a fuel the plutonium manufactured in the latter type.

When it comes to the problem of producing motive power the designers are going to be investigating ways and means of reducing the overall size and weight of the reactor which, let it be remembered, is purely the source of heat and will require to be followed by a fairly conventional thermodynamic cycle for the production of mechanical power.

For this purpose one visualises that there would be objections to the use of the larger graphite-moderated natural uranium reactors with their pressure vessels and heavy shielding, and that designers may turn to the fast fission or homogeneous reactors in order to have a very small core size and consequently reduce the weight of shielding that is required.

For certain applications there are possibilities of using pressurised light and heavy water reactors using the water both as a moderator and coolant. This would be particularly true of the heavy water reactor if the cost of producing heavy water can be reduced.

One of the problems determining the advance of this type of reactor will be the development of pressure vessels for higher and higher pressures.

In our land-based reactors, for the production of steam or electricity, shielding could be conveniently carried out in special grade concrete. When one considers that this may be of the order of six feet thick all round the reactor vessel, its size can be readily imagined.

Conversely alternative types of shielding, for example steel and lead, could be considered when smaller reactors are being designed for the production of power.

In cases where the saving of weight and space are of paramount importance and more costly materials may be used, designers may consider complex shielding using layers of neutron-absorbing material.

The Government White Paper Plan

The first industrial application of nuclear energy which is going to affect us all is the Government's decision to go ahead with the construction of nuclear power stations throughout the country, published in the White Paper in February last year, and it is appropriate at this stage I think to draw attention to certain points made in that Paper.

Fig. 9 shows the build up of electricity consumption, installed capacity and fuel used in this country between the years 1900 to 1955 and from these curves the annual increases in electricity demand, which have taken place, can readily be appreciated.

The use of electricity is now increasing at an average rate of about 7 per cent a year, which means that consumption is doubling every 10 years and there is little sign of reaching saturation in this country for many years to come.

The demand for electricity is still expected to increase rapidly and is likely to be about $3\frac{1}{2}$ times its present level in 20 years time.

The capacity of the public electricity supply system in this country at the end of 1954 was around 20,000 megawatts, whereas the total generating capacity estimated to be required in 1975 would be of the order of 57,000 megawatts and while some proportion of this would be supplied from hydro-electric stations and the thermal efficiency of coal fired power stations may continue to improve, the coal required for this capacity would be about 100 million tons or about $2\frac{1}{2}$ times as much as at present consumed. Although it is possible that some of the power stations would by then be operating on oil, by 1975 the rate of coal consumption might be rising by 4 to 5 millions tons a year.

In addition, every million tons of coal saved by burning oil means importing over half a million tons of oil.

With the Government's investment in nuclear power proposed in the White Paper, some 30 to 40 million tons of coal a year would be saved for the other users of solid fuel, whose demand would have been steadily rising in the intervening years. Although production of coal in this country has increased in the last 10 years, the production is unlikely to increase at the rate required to meet the increasing demand

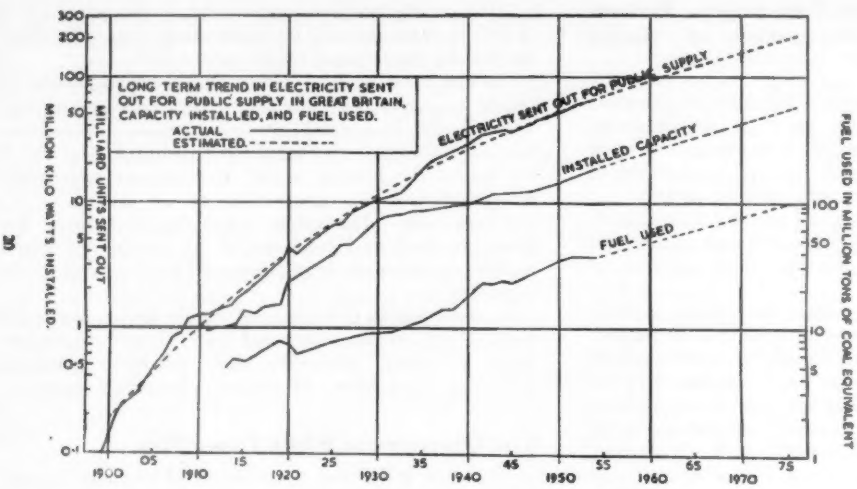


Fig. 9. The increasing demand for electricity.

for power, which will bring with it the opportunity for higher productivity throughout the country.

As an initial contribution to the additional electricity required up to 1975, the Government's policy is to construct twelve nuclear power stations to the following programme (see Fig. 10) :—

1. Two stations with gas-cooled graphite-moderated reactors starting about the middle of next year and coming into operation in 1960-61.
2. Two further stations operating 18 months later and having similar reactors but of improved performance.
3. The construction of four more stations starting perhaps in 1960 with a further four, 18 months later. These might come into operation in 1963-64 and 65. These stations are likely to be much more highly rated than the reactors in the first four stations and may be developments in the gas-cooled graphite-moderated types or in the liquid metal-cooled type in the latter cases.

On the assumption that nuclear stations would be operated as base load stations they would, by 1965, be producing electricity at the rate equivalent to that produced from 5 to 6 million tons of coal a year.

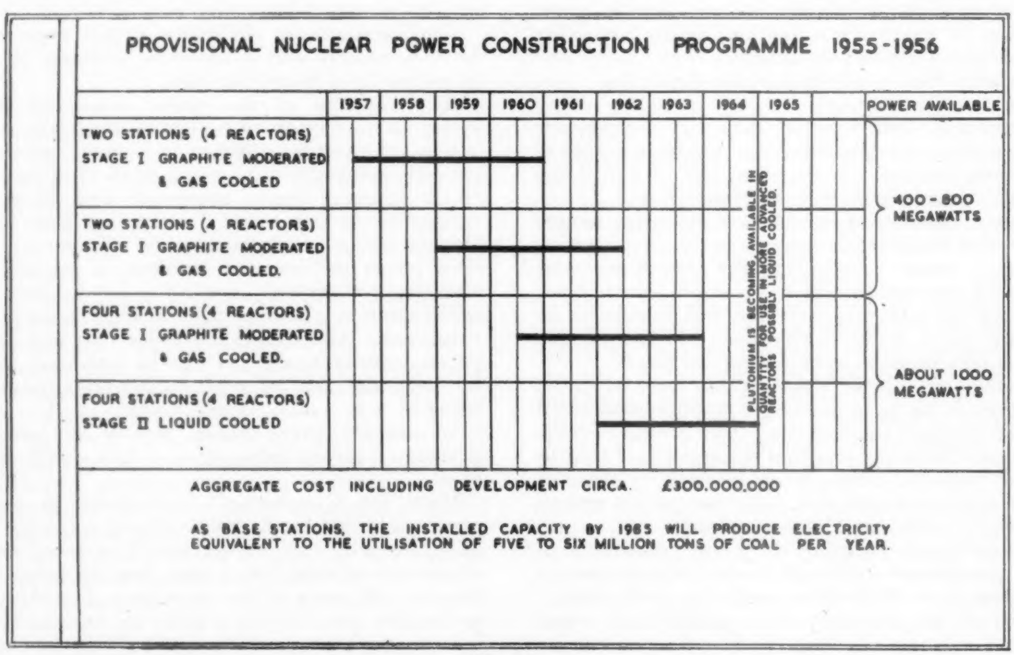


Fig. 10.

The plutonium from the early reactors would begin to become available in 1964 and would be available for enriching the fuel charges in later and probably liquid-cooled reactors, so that one can visualise a complementary chain of power stations throughout utilising both natural uranium and later on the more enriched fuels, depending on the particular design of the reactors in use.

The cost of this 10-year programme is estimated to be around £300,000,000, offset against which there would, of course, be the expenditure which would otherwise have been incurred by the electricity authorities providing new coal or oil-fired generating capacity in the absence of nuclear power. Consequently savings in the investment programme of the National Coal Board some years hence should also result, quite apart from the fact that we may have to conserve our available resources of solid fuel for other demands.

It has been estimated in the Government White Paper that electricity could be produced from the first industrial nuclear power stations at about 0.6d per unit allowing due credit for the plutonium produced, quite apart from any improvement in efficiency which may be built into the later stations.

Bearing in mind the increased cost of coal delivered to the power stations in this country, it may prove to be economical from about 1965 onwards to build nuclear power stations instead of conventional stations, as cheap power is an asset to an industrial country such as this and will have an immediate effect upon the costs of production.

The increased generating capacity required by 1965 and by 1975 with the estimated build-up of nuclear power is shown in Fig. 11.

Details of the Calder Project

I do not think that my remarks on power production from reactors would be complete without mentioning some of the details of our two Calder reactors, which will comprise the first nuclear power station in this country and will be the forerunners of the industrial power stations to be built by the Electricity Authorities. The Calder Hall reactors have already been shown on television and photographs of them under construction have been published in many of our national newspapers, so I have no doubt that some of you will remember their size. Contrary to some reports that have already been issued, the first of these two reactors will be working during the second half of this year. An artist's impression of the site is shown in Fig. 12.

As I have said, these are graphite-moderated reactors cooled by carbon-dioxide gas under pressure and a general diagrammatic arrangement of the reactor can be seen by referring again to Fig. 2.

It will be seen that the core of the reactor is surrounded by a concrete biological shield several feet thick. This shield is octagonal and is protected from thermal and radiation effects by a thermal shield made of 6-inch mild steel plate.

Induced draft air-cooling is supplied to the space between the thermal shield and the biological shield and the outlet air is exhausted 200 ft. above ground level from the two stacks on the pile building.

The mass of graphite moderator weighing over 1,000 tons is contained in a cylindrically-shaped pressure vessel. The machined graphite blocks have vertical uranium charge and control rod channels, the adoption of vertical channels simplifying the graphite structure and making the design of the coolant circuit more convenient.

The weight of the graphite is taken on a diagrid structure which consists of an "I" section ring girder spanned with steel girders forming a rectangular lattice (see Fig. 13). Across the members of the diagrid lattice are bolted 4 in. thick steel base plates which have holes in them to coincide with the channels in the graphite. The base plates support the graphite through a number of races which allow for differential thermal expansion of the diagrid and graphite.

The weight of graphite and diagrid is taken by brackets directly through the walls of the pressure vessel on to ten inverted "A" frames which rest on the thermal shield. These "A" frames are loosely bolted to the brackets on the pressure vessel and on to the thermal shield, the three contact surfaces of each "A" frame being radiused. In this manner, allowance is made for radial thermal expansion of the pressure vessel and diagrid, when the "A" frames roll slightly out of the vertical and the bolts ensure that the rolling surfaces do not slip.

The pressure vessel is of 2 in. welded steel plate and is about 40 ft. in diameter and approximately 60 ft. high. The construction of the vessel provided a novel and interesting job. Fabrication was carried out on the site, all parts (except the inlet manifold) arriving piecemeal. Extensive site welding facilities were set up and the vessel was built into five main sections, namely the bottom dome, the two parallel centre sections, the diagrid and finally the top dome.

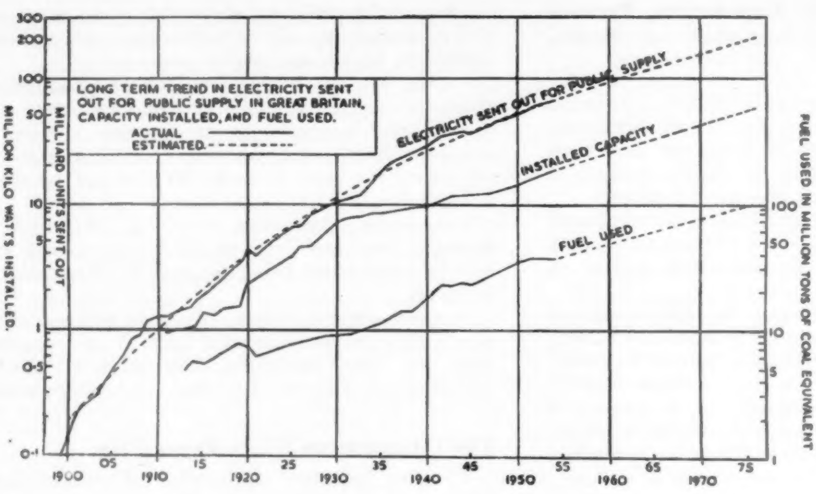
As each section was completed, it was transported to the lifting area where a 100-ton crane was used to hoist the sections and to lower them through the pile vault roof, the final welds being completed *in situ*. Each butt weld was radiographed and all-important fillet welds were examined by crack-detection techniques.

The task of stress relieving the completed vessel was achieved by radiant heating which required a peak electrical load of about 1½ megawatts. The vessel temperature was brought up to over 550 °C and held there for 8 hours before being allowed to cool slowly and evenly.

The vessel was then subjected to pressure test. The use of hydraulic testing techniques would have overloaded the structure and for this reason a pneumatic test was carried out. A constant check on the behaviour of the vessel was maintained by means of strain and other gauges.

The final test was under vacuum at 1/10th of an atmosphere pressure and was done by means of the large rotary vacuum pump which is part of the operational equipment required for exhausting the vessel when charging or changing the CO_2 coolant.

The reactor charge and discharge arrangements are accommodated no the pile vault roof along with the pile control and shut off gear. Emerging from the reactor top dome are the charging tubes which



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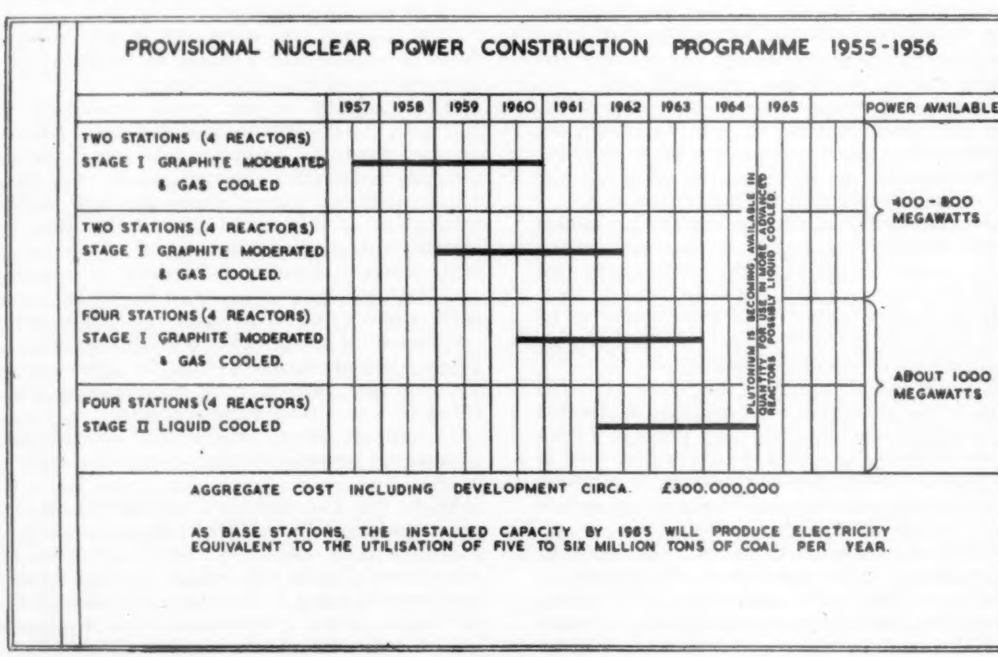

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The mass of graphite moderator weighing over 1,000 tons is contained in a cylindrically-shaped pressure vessel. The machined graphite blocks have vertical uranium charge and control rod channels, the adoption of vertical channels simplifying the graphite structure and making the design of the coolant circuit more convenient.

The weight of the graphite is taken on a diagrid structure which consists of an "I" section ring girder spanned with steel girders forming a rectangular lattice (see Fig. 13). Across the members of the diagrid lattice are bolted 4 in. thick steel base plates which have holes in them to coincide with the channels in the graphite. The base plates support the graphite through a number of races which allow for differential thermal expansion of the diagrid and graphite.

The weight of graphite and diagrid is taken by brackets directly through the walls of the pressure vessel on to ten inverted "A" frames which rest on the thermal shield. These "A" frames are loosely bolted to the brackets on the pressure vessel and on to the thermal shield, the three contact surfaces of each "A" frame being radiused. In this manner, allowance is made for radial thermal expansion of the pressure vessel and diagrid, when the "A" frames roll slightly out of the vertical and the bolts ensure that the rolling surfaces do not slip.

The pressure vessel is of 2 in. welded steel plate and is about 40 ft. in diameter and approximately 60 ft. high. The construction of the vessel provided a novel and interesting job. Fabrication was carried out on the site, all parts (except the inlet manifold) arriving piecemeal. Extensive site welding facilities were set up and the vessel was built into five main sections, namely the bottom dome, the two parallel centre sections, the diagrid and finally the top dome.

As each section was completed, it was transported to the lifting area where a 100-ton crane was used to hoist the sections and to lower them through the pile vault roof, the final welds being completed *in situ*. Each butt weld was radiographed and all-important fillet welds were examined by crack-detection techniques.

The task of stress relieving the completed vessel was achieved by radiant heating which required a peak electrical load of about 1½ megawatts. The vessel temperature was brought up to over 550°C and held there for 8 hours before being allowed to cool slowly and evenly.

The vessel was then subjected to pressure test. The use of hydraulic testing techniques would have overloaded the structure and for this reason a pneumatic test was carried out. A constant check on the behaviour of the vessel was maintained by means of strain and other gauges.

The final test was under vacuum at 1/10th of an atmosphere pressure and was done by means of the large rotary vacuum pump which is part of the operational equipment required for exhausting the vessel when charging or changing the CO_2 coolant.

The reactor charge and discharge arrangements are accommodated no the pile vault roof along with the pile control and shut off gear. Emerging from the reactor top dome are the charging tubes which

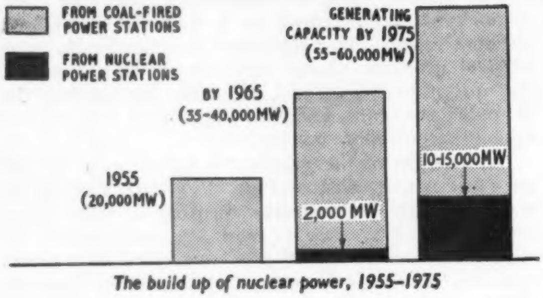


Fig. 11.

Fig. 12. An artist's impression of the Calder Project.

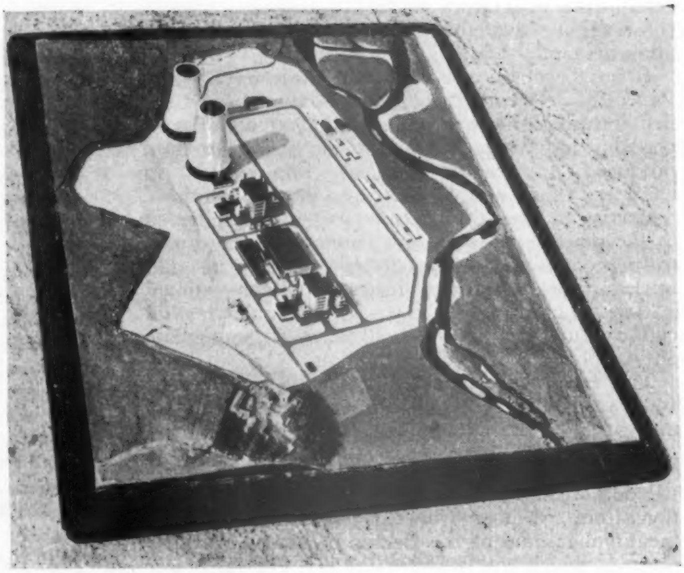


Fig. 13. Looking down the half-finished pressure vessel to the diagrid.

terminate at the upper surface of the pile vault roof. An overhead crane lowers the charge chute into the desired charging tube, and the charge machine supplies fuel elements from a magazine. Conversely, the discharge machine removes spent fuel elements by withdrawing them up the charge chute and placing them in a basket where they are kept cool. The basket is lowered into a coffin at the bottom of the discharge well, the coffin lid is automatically positioned and the coffin is withdrawn from the discharge room to be transported to the cooling pond.

The control rods and shut-off rods are made of stainless steel tube lined with boron steel fillers and are suspended through the roof of the pile.

The hot CO_2 coolant is led away from the top of the pressure vessel by circular mild steel ducts of 4 ft. 6 in. diameter to the four heat exchangers which are situated at the corners of the pile building (see Fig. 14). The cool CO_2 coolant from the base of each heat exchanger is boosted by four main blowers and returned to the inlet manifold at the base of the pressure vessel. Motorised isolating valves of the wedge gate type are included in each hot and cold duct and flow cascades are fitted at the bends of the ducts. The problem of accommodating the large thermal expansions between the pressure vessel and the heat exchangers under various conditions of operation was solved by the use of "hinged bellows" in the ducts. The duct flexibility is obtained from the bellows, which are of welded steel plate, while the thrust due to the internal pressure of the gas is taken by the pin joint in the bellows assembly. The whole of the duct structures are carried on spring-type constant load supports.

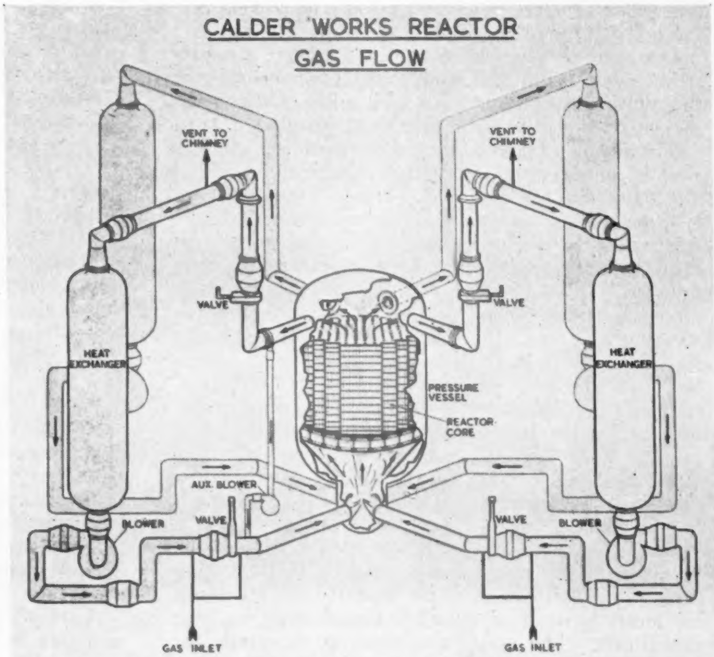
The four CO_2 coolant blowers are of the single stage centrifugal type with an overhung impeller. The overhung impeller arrangement has the advantage of requiring only one gland, but it has the additional advantage of facilitating an arrangement in which the gland and bearings can be so located that access to them can be obtained without exposure to radiation which is above tolerance level. The gland is of the face seal type.

It was decided that control of the mass flow of coolant could best be carried out by controlling the speed of rotation of the blowers in preference to varying the static pressure of the coolant system as a whole, thus the D.C. motors which develop some 1800/2000 H.P. each are supplied from motor generating sets in the blower house which permit the blower speed to be varied over the range of 10 : 1 on the Ward Leonard system. About 2 per cent. of the mass flow through each blower is taken from the downstream side of the blower, filtered and re-introduced to the system on the upstream side of the blower with a view to preventing the accumulation of graphite dust and iron oxide in the coolant system. A constant check is kept on the water content of the coolant, which is kept down by alumina drying units which hold the dew point of the CO_2 below the necessary limit.

As in the Windscale piles, continuous monitoring of the coolant gas stream for the detection of burst fuel elements is also carried out.

Over 20 tons of carbon dioxide are required to complete the filling of the reactor and coolant circuits. Charging is carried out by exhausting the system and then admitting CO_2 which is generated from four

Fig. 14.



liquid CO_2 storage tanks. Purging by repeated charging and discharging is necessary in the first filling.

Each of the four heat exchangers is contained in a vertical steel pressure shell of $1\frac{5}{16}$ in. steel plate; they are about 18 ft. in diameter and some 70 ft. high. The 30,000 sq. ft. of water heating surface comprising high pressure and low pressure economiser, evaporator and superheater sections is made of 2 in. overall diameter mild steel tubing through which the water and the steam pass. The gas surface of the tubes is extended by the use of elliptical steel stud tube fin construction.

Flow in the evaporator sections is by forced circulation from electrically driven pumps, which maintain a circulation rate of about four times the steam output of the section. Each evaporator has a single steam drum, 4 ft. in diameter and 18 ft. long, which contains conventional cyclones and scrubbers. Particular attention has been given to minimising the possibility of steam or water leaking into the coolant circuit by keeping the number of tube joints contained within the pressure shell to a minimum. All tube joints sited within the first heat exchanger to be assembled, were subjected to an abnormally high pressure test followed by a stringent vacuum test. The ends of each tube element pass separately through a sleeve in the pressure shell so that if leakage should occur at a joint, steam will escape to atmosphere. As in the case of the reactor pressure vessel the final assembly of the heat exchangers was done on site.

Each heat exchanger arrived in nine main sections consisting of the dished ends, the six circular centre sections and the skirt.

After the heat exchangers were assembled and inspected, the final welds were stress relieved by inductive heating and the heat exchangers were lifted on to their concrete plinths by using a pair of 100-ton gin poles. One of these lifts is shown in Fig. 15.

It would be possible to consider a three pressure steam cycle using separately fired super-heaters for the high-pressure steam, but such additional complications do not at present seem to be justified.

The steam is taken to the generator house which is situated between the pile buildings where four turbo-alternator sets are installed. The turbines are two-cylinder reaction machines of established design. The L.P. cylinder has twin exhausts which discharge into a surface condenser operating at $1\frac{3}{4}$ in. Hg. absolute pressure, i.e. at a temperature of about 38°C (100.4°F). The condensate is passed through a de-aerating plant and the steam cycle is completed by the H.P. and L.P. feed water pumps which return the water to the economisers. Each turbine is directly coupled to an air-cooled alternator of standard design and having continuous maximum rating of 23 megawatts at 11 kV. Power is exported through standard transformers, switchgear and transmission equipment to the Central Electricity Authority's grid lines.

A separate "dump" condenser is provided in which up to the full-load steam production of the heat exchangers may be condensed without passing through the turbines. The condensate from the dump condenser is de-aerated and fed back into the heat exchangers. The dump condenser is essentially for use during start-up and shut-down of the plant, but if required it will permit the reactors to be run at full load for plutonium production in the event of turbine outage.

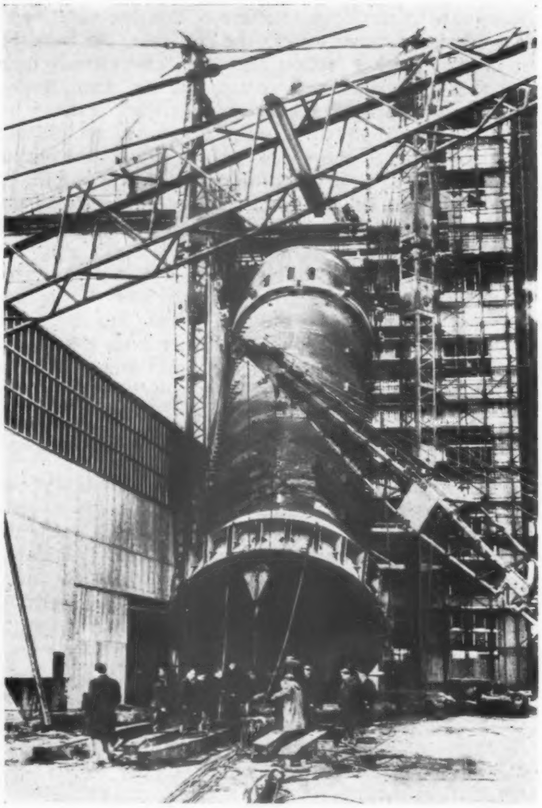


Fig. 15. Lifting one of the heat exchangers.

A closed-circuit cooling water system is employed for the condensers, with four electrically driven pumps of 640 H.P. each and two natural draught cooling towers. The cooling towers which are somewhat larger than normal being 290 ft. high and 220 ft. in diameter at the ring beam, are each capable of cooling 3,000,000 gallons of water per hour by 10°C.

Two further views of the Calder Reactors to give a more general impression are given in Fig. 16, which shows the reactor with chimneys and heat exchangers in position, and Fig. 17, which gives a view of the Calder project from Windscale Factory.

Future Prospects

For the immediate present and in particular for the production of electricity or steam from land-based reactors, our future prospects may be based on reactors, similar in many ways to the Calder Hall type, whereas later on developments in the alternative types of reactor will obviously widen our field of choice.

Let us consider for a moment, therefore, the Calder Hall type of reactor.

One of the limiting factors in the design of these reactors is the size of pressure vessel which can reasonably be constructed. If the volume of the

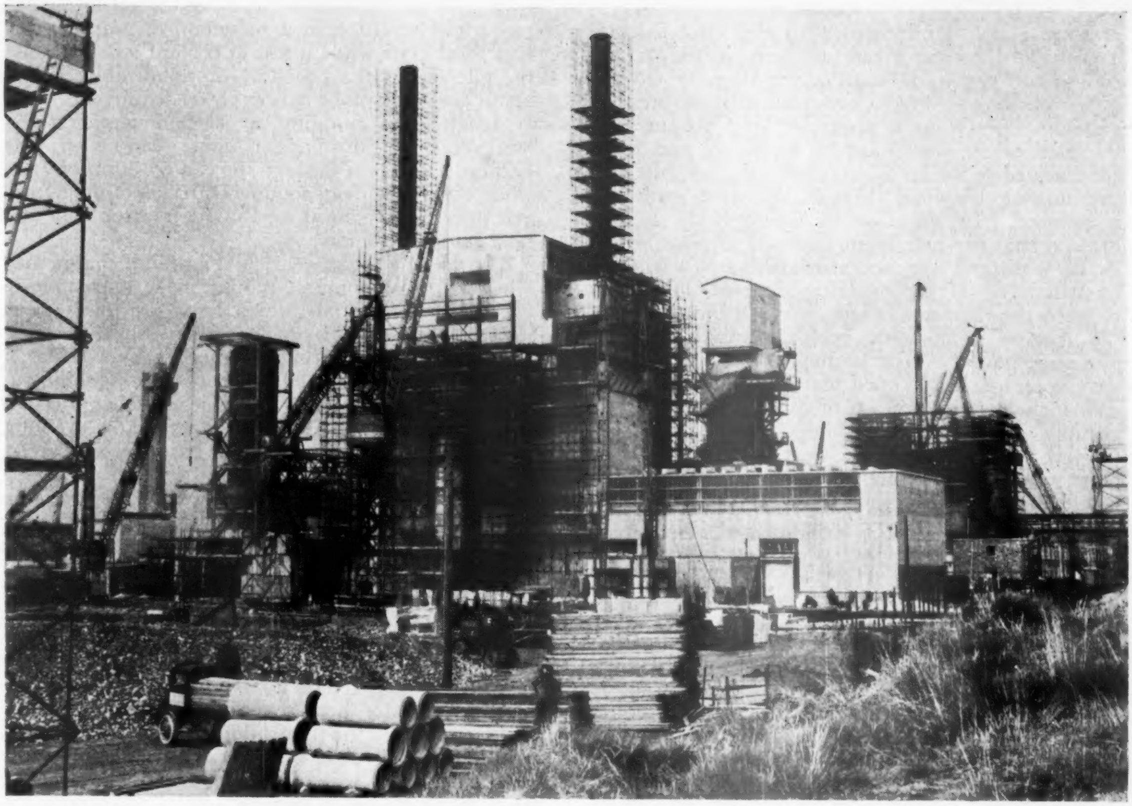


Fig. 16. Reactor with chimneys and heat exchanger in position.

Fig. 17. A view of the Calder project from Windscale Factory.

pressure vessel is increased, then the total thermal capacity of the reactor can also be increased and the capital cost per lb. of steam or per kilowatt sent out is brought down. But to construct a larger pressure vessel to operate at a given working pressure the thickness of the shell must be increased, and more complicated problems of supporting the graphite and transmitting the load through the shell walls are introduced. In the case of Calder Hall it was decided that the maximum thickness of plate which could withstand the necessary pressure was fixed immediately. If the working pressure had been reduced the diameter of the core and the output of the reactor could have been increased, but the pumping power for circulating the coolant would have gone up. It is hoped that future developments will include the welding of thicker gauge plate, possibly up to 3-in., enabling the use of larger pressure vessels to become practical. The thicker plate would alternatively allow working pressures to be lifted for a given pressure vessel size and this would result in a lower blower power being required to remove a given amount of heat. Another line of approach is to use a spherical pressure vessel which, with a given plate thickness, could be made nearly twice the diameter of a cylindrical container. Considered purely as a problem of pressure vessel design the sphere offers very great advantages, but it gives rise to difficulties in the support of the graphite structure of the moderator within it. Also the costly biological shield is larger for a given total thermal capacity, but this difficulty may be alleviated by incorporating the biological shield in the pressure shell.

The search for a better reactor coolant is continuous, but as happens so often in engineering a compromise between various conflicting requirements must be accepted. Neutron economy is one of the main problems of reactor design and parasitic neutron losses to the coolant must be small while due consideration must be given to the characteristics of the coolant as a moderator and under conditions of irradiation. The coolant must be compatible with the circuit components such as the can metal, the pressure vessel and the moderator while (since defects of canning cannot be absolutely eliminated) its chemical affinity for the fuel itself must not be overlooked. One of the most suitable coolants is helium which, besides being chemically stable, has a high specific heat and offers a negligible ability to capture thermal neutrons. The main objections to its use in Great Britain are the high cost and the fact that it is not an indigenous material.

Carbon dioxide on the other hand is cheap and readily available, while its neutron capture ability is entirely satisfactory. In addition, it is fairly stable chemically under the Calder Hall reactor operating conditions, where it does not react with the graphite moderator to any important extent.

Nitrogen is not attractive as it is a poor coolant, the circulation of which would absorb an unduly high proportion of the energy generated, while its neutron capture is high.

Hydrogen on the other hand offers interesting possibilities as a coolant. Firstly, it would act as a moderator resulting in a reduction of graphite and structural costs while a loss of coolant would reduce the pile reactivity. Secondly, it would only require about one-tenth of the blower power required for CO_2. It reacts with uranium at certain temperatures, however, and this might cause serious trouble because it can pass through the can by diffusion even while the can remains sound. Diffusion of the hydrogen into the structural steel of the reactor may also be a cause of trouble.

The use of a slightly enriched uranium charge may also lead to economies. It may make it possible to use canning materials which have previously been rejected because of their high neutron capture ability. The use of such materials may make it possible to use higher fuel element operating temperatures with safety and so to achieve higher thermodynamic efficiencies. A slightly enriched uranium charge toward the outside of the reactor core enables flattening of the neutron flux distribution across the core to be carried out, which in turn increases the total thermal capacity of the pile and hence the electrical output of the station.

In the pure engineering field, there can be no doubt that the design of heat exchangers can be considerably improved and cheapened. The problems of raising steam by transferring heat to the water from a perfectly pure and clean gas has never before had to be considered on a large scale. The stud tube extended surface heat exchanger which is used at Calder Hall had the tremendous advantage that this type of heat exchanger surface was already established industrially and was in mass production. It is not an ideal type of extended surface for the absorption of heat from a completely pure gas. Each one of the Calder Hall heat exchangers weighed some 200 tons and the problem of transporting the sections, assembling them on the site and lifting the complete heat exchanger into position caused many anxious problems. There is no doubt whatever that a cheaper, lighter and more compact heat exchanger could be developed to deal with the problem.

Considering now future developments in alternative types of reactor, it follows that in designing a reactor for production of industrial power that we must release our heat at the highest possible temperature. There is no nuclear-physical reason why the fission process should not be operated at a very high temperature indeed, but there are plenty of engineering and metallurgical considerations which restrain us from any such attempt at the present time. At the present stage it is more important to be successful than to be clever for our first power-generating nuclear reactors, therefore we should content ourselves with securing reliable operation at modest temperatures. It cannot be over-emphasised that, whereas the dimensions of the core of a nuclear reactor are determined primarily by nuclear physical considerations, the permissible rate of heat release is entirely a question of the engineering design of the cooling system and of the choice of materials.

Because of the need for a moderator and because of the relatively large quantity of natural uranium required to give a critical assembly, natural uranium reactors tend to be large in size. However, the use

of enriched uranium, that is, uranium which has been subjected to a physical process to increase the percentage of fissionable Uranium 235 which it contains, introduces an additional degree of freedom into the reactor design. The fact that the fissile uranium 235 is less diluted with Uranium 238 makes it possible to reduce the total uranium charge, and so the overall dimensions of the reacting core can be reduced. If enrichment is carried far enough the way is open for the construction of reactors of a different type to which I previously referred, in which there is no moderator and in which the fission process is carried on by intermediate or high-energy neutrons. These so-called ' fast reactors ' could be fuelled either with uranium highly enriched in Uranium 235 or by an artificial blend of Plutonium and Uranium 238. The cost of enriching uranium is high, and to make the best use of this expensive material we must develop engineering and metallurgical techniques which enable us to remove the maximum quantity of heat from a given quantity of fuel—that is, we must achieve high specific ratings on our fuel elements. One can thus visualise a sequence of reactor designs, forming an ascending scale of enrichment and specific thermal rating and a descending scale of core size.

In the case of a graphite-moderated, gas-cooled thermal reactor, using natural uranium, the heat rating in megawatts per ton of uranium will be relatively low (as I said, around 1 megawatt per ton). Conduction of heat within the fuel elements themselves does not therefore present a serious limitation. With this type of reactor it is the heat transfer from the surface of the fuel elements to the gas stream that determines the final power rating. The technical design of the coolant channels and of the extended surfaces of the fuel elements is, therefore, of great importance if the optimum output is to be achieved with a given limitation on the surface temperature. One cannot improve the heat transfer rates beyond a certain point by increasing the gas velocity, since the pumping power would become prohibitive. Again one cannot improve the heat transfer rates by increasing the amount of the extended surface beyond a certain point, since the canning material acts as an absorber of neutrons and if we increase the quantity which is present we shall have to increase the charge of uranium needed to reach the critical size. The only independent variable which can be increased so as to give a substantial gain in the power rating of the reactor is the surface temperature of the fuel elements. Here, however, one is back to metallurgical limitations which at present limit us to temperatures of the order of 400 °C (752 °F).

After irradiation, unless we are wastefully to throw away our fuel elements, they must be put through a chemical separation process to remove the fission products. This chemical processing is very expensive and we must therefore extend the periods between chemical processing, that is, increase our periods of irradiation, if we are going to reduce our cost of operation.

The design of a fuel element which can withstand a long period of irradiation is difficult; growth and distortion of the uranium will occur during irradiation and it is necessary for the container to accommodate these changes without bursting and allowing leakage of active fission products from the irradiated metal into the coolant stream. It is also essential that the irradiated cartridge can be removed with certainty, either at the end of the proper period of irradiation or in the event of individual failure, despite any distortion that may have taken place.

Consider next a reactor having a higher heat output per ton of fuel in the reacting core; in which case we are thinking of heat releases of a few megawatts per ton of fuel. With these higher heat ratings we begin to run into heat transfer problems connected with the elements themselves. So much heat has to be conducted through the uranium that the temperature at the centre of the metal starts to get undesirably high unless we use thinner fuel elements. The use of pressurised water as the coolant enables the necessary heat transfer rates from the surface of the fuel elements to be achieved, but we may get appreciable thermal stresses in the material of the containers.

If we go a step further and consider an intermediate or fast reactor without any moderator we must face still higher heat ratings. Heat conduction within the uranium and through the walls of the fuel elements container is now very important. The uranium will certainly be plastic and may be in a near-molten state in the centre of the core. Gaseous fission products formed within the metal may produce large internal pressures there, or may diffuse outwards and build up an internal pressure within the can. Large thermal stresses will be set up in the cans, owing to the steep temperature gradients, and the material will almost certainly be taken beyond the elastic range. Minor variations in the dimensions of the fuel elements or in the distribution of coolant velocity may lead to distortion of the fuel elements.

Whatever type of reactor it may be, we have the problem of compatibility of uranium, canning material, coolant, and moderator under appropriate conditions of temperature and irradiation. It is not surprising that the choice of materials is difficult. If any of the materials of construction are slightly soluble in the coolant we may have mass transfer effects to contend with. Irradiation may bring about chemical reactions between the coolant and the material of the coolant channels or fuel elements. It may, alternatively, alter the rate of reactions which would otherwise occur more slowly. The result of this mass transfer effect may be the removal of material from one part of the coolant circuit and deposition in another.

It is reasonable to think of nuclear reactors in an ascending scale of specific heat rating of their fuel elements. At the bottom of this scale is the graphite-moderated gas-cooled reactor which I have described in some detail. It is essentially a heavy, land-based reactor, using low specific ratings, but economical because it does not need to make use of expensive materials of construction. It can, perhaps, be regarded as the slow-speed reciprocating engine of the reactor world, reliable and almost conventional in design.

At the other end of our reactor scale, we have the fast fission reactor, very much more highly rated and using expensive and rare materials of construction.

High ratings are necesssary in order to make this reactor economical because the fissionable material which it uses as a fuel is extremely expensive. It can, perhaps, be regarded as the gas turbine of the nuclear reactor world.

In between these two extremes are dozens of alternative types of reactor making use of fast neutron, intermediate neutron, or thermal neutron velocities; using no moderator or light water, heavy water, beryllium or graphite as moderators; using gases, water, hydro-carbons or liquid metals as coolant in any combination that can be imagined.

Which of these reactors will at future dates be found to be economical is more than can be safely predicted today. We in Great Britain are attacking the two ends of the scale; we have designed the graphite-moderated gas-cooled reactor which will soon be producing large quantities of industrial power at Calder Hall, and we are building the fast reactor at Dounreay. In between these two extremes we are applying our resources at those intermediate points which appear from time to time to offer the greatest promise.

The development of highly rated reactors is essential, because such reactors are needed to burn the bi-product plutonium produced in the reactors of conservative rating which are built as the first step in our industrial programme. It would, however, be a great mistake to assume that these conservatively designed reactors of the graphite-moderated gas-cooled type have only a limited future. With development, the reciprocating steam engine held its own over a period of nearly 200 years as an economical prime mover and the simplicity and reliability of the gas-cooled reactor will entitle it to a similar place in the history of nuclear power.

In conclusion, I would draw attention to the fact that there is great scope in reactor design for resourcefulness and many more types of reactor are feasible. It is possible during nuclear fission to obtain temperatures around 1,000,000°C and only the limits set by our present-day knowledge, both in physical and metallurgical technique, prevent the production of really large amounts of high grade heat by nuclear fission in reactors of comparatively small dimensions.

As it has been calculated that the complete fission of one ounce of uranium would release about 640,000 K.W.H. of energy or nearly three million times as much as the same weight of coal, there are ample reserves of energy which the nuclear design engineer will undoubtedly strive to extract.

I have already said that capital costs are for the present high and reactor auxiliary running power is still higher than that of the usual boiler auxiliaries in orthodox coal or oil burning plant; but within the framework I have outlined today, I feel even the most pessimistic of men will agree there is in nuclear fission one of the world's largest sources of useful energy.

APPENDIX

Simple Explanation of the Underlying Theory of Atomic Energy and Explanation of Terms

The atoms of which all matter is composed can be visualised as tiny solar systems. They have an agglomerate of particles in the centre which is called the nucleus and which corresponds to the sun in our solar system. Around this nucleus particles called electrons move in orbits, just as the planets move around the sun. Each electron carries a unit negative electrical charge.

For our purpose the nucleus can be considered as containing two types of particle: protons, each of which carries a unit positive electrical charge, and neutrons, which are uncharged particles. Because a normal atom is uncharged electrically, it follows that in such an atom the number of protons in the nucleus is the same as the number of electrons moving in orbits about it.

The chemical properties of any atom depend only on the number of protons in the nucleus; atoms with the same number of protons in the nucleus always have the same chemical properties. For any given number of protons in the nucleus, however, the number of neutrons may vary, and when the number of neutrons in the nucleus is changed the mass and physical properties of the atom are consequently changed. Two atoms which have the same number of protons in the nucleus (and therefore the same chemical properties) but different numbers of neutrons in the nucleus (and therefore different physical properties) are called isotopes of the same chemical substances.

Because the atoms are made up of electrically-charged moving particles, they obviously have an energy content.

When a chemical reaction between two or more atoms is carried out, the nuclei of these atoms remain separate and unchanged. All that happens is that the movement of the electrons in their orbits is modified. The atomic structure which results from such a chemical reaction also has an energy content and, if the energy content of the atomic structures which exist after a chemical reaction is less than the energy content of the atomic structures which existed before the chemical reaction, the difference in these energy contents is released, normally as heat.

In a nuclear reaction the change which takes place does not affect only the movement of the electrons around the nuclei; changes take place within the nuclei. They may be built up into more composite structures, or they may be broken down into smaller structures. As in the case of a chemical reaction, the difference between the energy content of the atomic structures which exist prior to the change and those which exist after the change is released as heat energy. In the case of a nuclear reaction, however, the difference is very much greater than it can be in the case of a chemical reaction and, for this reason, the heat evolution from an exothermic nuclear reaction can be of the order of a million times greater than the heat evolution which can be obtained by

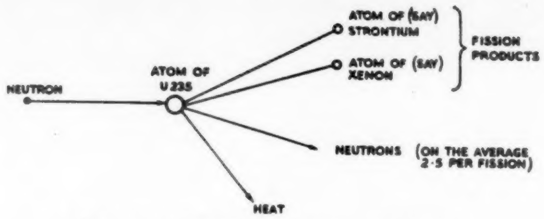


Fig. 18. Fission in an atom of U235.

carrying out chemical reactions with similar quantities of material.

Unfortunately, from the point of view of securing energy from nuclear reactions, it is very difficult to carry out such reactions under normal conditions. There is, however, one exception, namely, nuclear fission. Fissionable atoms have a large number of protons in the nucleus ; when the nucleus of a fissionable atom is struck by a neutron the whole complicated atomic solar system breaks down into two separate solar systems, each of them having approximately half the number of protons in the nucleus and half the number of electrons moving about it. These resultant atoms are called the fission products. When nuclear fission takes place the energy content of the resulting systems is less than the energy content of the initial system, and the balance of energy is released as heat. The result of a nuclear fission is, therefore, the formation of fission products, heat, and a variable number of neutrons. Only one fissionable atom exists in nature, namely, the isotope of uranium, which has a mass of 235. The process of fission in such an atom is shown in Fig. 18.

In this reaction, an average of about 2.5 neutrons is released from every fission that takes place. If fission takes place in a sufficiently large mass of fissile material, the neutrons which are released can be used to cause further fissions and the rate of fission increases exponentially throughout the mass (Fig. 19). Some neutrons are inevitably lost from the surface of the mass of fissile material ; if the number lost is so great that the number per fission remaining to cause further fissions is less than one, the chain reaction will become convergent instead of divergent and will die out. The larger the mass of fissile material, the less likely this is to occur because the number of atoms available to be struck by a neutron increases on a cube law, whereas the surface from which they can escape increases on a square law. The minimum mass of fissile material throughout which the action can proceed is called the critical size.

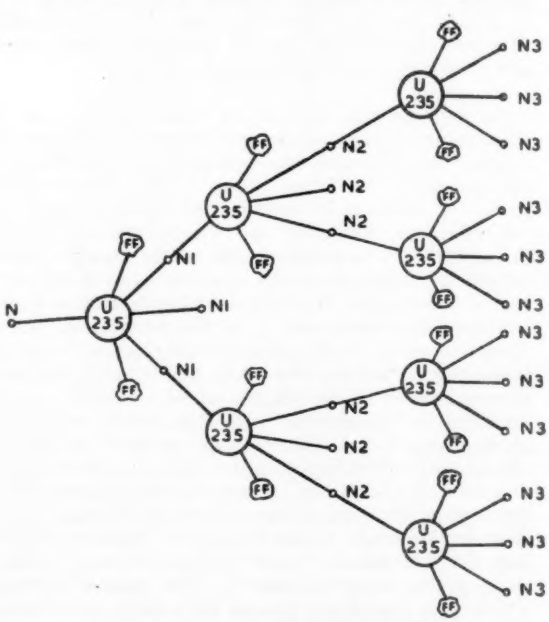


Fig. 19. Chain reaction with U235.

Natural uranium contains only 0.7 per cent of the fissionable isotope U235. The remainder is U238, an isotope which is not fissionable. The fissionable U235 cannot be separated from the U238 by chemical processes, because, chemically, the atoms are identical. It can, however, be separated by physical processes, and the one most frequently used is called gaseous diffusion. In this process, advantage is taken of the fact that lighter molecules diffuse more readily through porous membranes than heavier molecules. Uranium which has had its content of fissionable U235 increased by treatment in a diffusion plant is called enriched uranium.

When the nucleus of an atom of U238 is struck by a neutron, fission does not take place, but the neutron is captured in the nucleus to form an isotope of uranium (U239) which does not exist in nature. This isotope is unstable and after an interval of time it ejects a unit negative charge from its nucleus. This is equivalent to gaining a positive charge in the nucleus and therefore the new atom has 93 positive charges (protons) in the nucleus ; it therefore ceases to be uranium and is an atom which does not exist in nature and which is called neptunium. The neptunium atom is also unstable and repeats this process forming an atom which has 94 positive charges in its nucleus. This is the atom of plutonium ; it is a reasonably stable atom, but like Uranium 235, it is fissionable.

We can therefore start a chain reaction by bombarding the nucleus of an atom of U235 with a neutron ; fission products will be formed, heat will be evolved and on the average 2.5 neutrons will be emitted. We will assume that we inevitably lose an average of 0.5 of a neutron, and that we use one of our remaining neutrons to be absorbed by an atom of U238, whilst the other neutron strikes an atom of U235 to cause a further fission with which the whole process can be repeated. This is shown in Fig. 20 and is what happens in an ordinary atomic pile.

As before, the centre part of the atomic pile where these changes are taking place and which is called the core must be of a certain minimum size (the critical size) otherwise the loss of neutrons from the pile will be too great for the chain reaction to continue. Once we are above the critical size, we can carry on our chain reaction and build it up to any intensity which is convenient. This intensity is in practice determined by our ability to remove the heat from the core and is referred to as the specific rating of the fuel.

Fig. 20. Formation of Plutonium in an atomic pile.

In a reactor which uses natural or slightly enriched uranium, there is a strong probability that all the neutrons emitted from any fission will be absorbed by atoms of U238 and will not cause further fission by striking atoms of U235. This is obvious, because there are about 140 atoms of U238 available as targets for every atom of U235 which exists in the uranium. We must do something to remedy this or our chain reaction will die out. When the neutrons are emitted, they are travelling at high velocities (fast neutrons). By making them travel more slowly we can increase the probability that they will cause further fissions in U235 and correspondingly decrease the probability that they will be absorbed in atoms of U238. In order to slow down the neutrons, we let them strike and share their energy with suitable atoms. Materials which can be used for slowing down neutrons in this way are called moderators ; the ones most frequently used are graphite and heavy water. The neutrons are slowed down in the moderator to velocities which correspond with the temperature of the moderator and, after slowing down in this way, they are called thermal neutrons and therefore a reactor which uses a moderator is called a thermal reactor.

If we desire a reactor to work at a steady output, the number of neutrons available to cause further fissions must remain constant. We can achieve this state of affairs by absorbing any neutrons in excess of this quantity. This is done by putting more or less of neutron-absorbing material into the pile. The material normally used for this purpose is boron and it is inserted or withdrawn from the pile in what are called control rods. The further the control rod is pushed into the pile, the more neutrons it will absorb and the fewer neutrons will be available for causing further fissions. Similar rods available for shutting down the pile in emergency are called shut-off rods.

In the core of a pile there is tremendous radioactivity, which would kill operatives working around it if they were not shielded from the neutrons and from the gamma-radiation (radiation similar to X-rays). This is done by surrounding the core with thick concrete walls which bring the intensity of radiation down to a level which is biologically safe. They are therefore called the biological shield. These concrete walls would be damaged if they were too heavily bombarded by thermal neutrons from the core and they are, therefore, lined with thick steel plates to absorb these thermal neutrons ; these plates are therefore called the thermal shield.

In the thermal reactor we have had to use a moderator to slow down our neutrons, simply to ensure that too many neutrons were not absorbed by the non-fissionable U238. If our nuclear fuel consists mainly of fissionable material, we shall be able to maintain our chain reaction without slowing down our neutrons because there will not be enough U238 present to absorb so many neutrons as to damp out the chain reaction. We shall therefore be able to work without a moderator and to use fast neutrons to cause further fissions. Such a reactor therefore is called a fast reactor. Because there is no moderator in a fast reactor, there is less likelihood of uselessly losing neutrons by absorption. With this greater economy of neutrons it may be possible to have so many neutrons absorbed in atoms of U238 that the number of atoms of plutonium created will be greater than the number of atoms of U235 destroyed. We shall then have bred an additional quantity of fissile material and, for this reason, reactors of this type are sometimes called breeder reactors. The material from which the new fissile atoms are bred is sometimes called the fertile material.

INVESTING IN BETTER FUEL UTILISATION

by L. CLEGG, M.B.E., A.M.I.Chem.E., M.Inst.F.

Mr. L. Clegg received his technical training in engineering and fuel technology at the Technical School, Rochdale; College of Technology, Manchester; and Heriot-Watt College, Edinburgh. After many years industrial experience in the paper, low-temperature carbonisation, metallurgical and chemical process industries he joined the Ministry of Fuel and Power in 1948, when he was responsible for developing the Ministry's Mobile Testing Unit services and industrial surveys. He transferred to N.I.F.E.S. in May, 1954, and was appointed Chief Engineer in November of that year. He is a member of various committees sponsored by the British Coal Utilisation Council and the City and Guilds of London Institute. Mr. Clegg is a member of the Institute of Fuel and an Associate Member of the Institution of Chemical Engineers. He is the author of a number of Papers covering Heat and Power subjects, and was joint author of Papers on "Heat Balances in Practice", "Drying of Pastes, Powders and Crystals", and "Fuel Heat and Power Auditing" which were presented to the Institute of Fuel. He was awarded the M.B.E. in 1951.

Mr. L. Clegg

IF we are to respond to the challenge made by Mr. R. A. Butler when, as Chancellor of the Exchequer, he said that we could double our standard of living in 25 years, we must budget on the assumption that there will be a rapidly increasing demand for energy. "International Co-operation for Productivity", "Research", "Automation", "Better Machine Tools", "Better Human Relations in Industry", will have little meaning in the end unless full consideration is given not only to adequate supplies of all forms of energy required by industry, but also to the efficient utilisation of that energy.

A detailed examination into industrial productivity during the past 50 years will show that as a nation there has been a gradual but definite decline in our position relative to that of our major competitors. Our position started to weaken around the turn of the century after the initial impetus of the industrial revolution had died down, and other nations were increasingly improving their own production efficiencies. These improvements have continued so steadily that our position as a major workshop of the world is now severely threatened. It may be argued that for some of them, who are merely catching up, an increase is much easier than for us who have to break new ground. The fundamental fact remains, however, that fifty years ago we lived largely on our exports to the backward peoples of other countries, people who had a very low standard of living and are now going ahead, with alarming strides, in education and technology, and are increasingly disputing the higher standard which we enjoy from no greater human effort than theirs. These people will have less and less requirement for our exports as they replace them by goods of their own manufacture. If we are even to maintain our standard of living, let alone

ENERGY HELPS EXPAND PRODUCTION

IN 50 YEARS LABOR FORCE INCREASED ONLY 119% PRODUCTION 372%

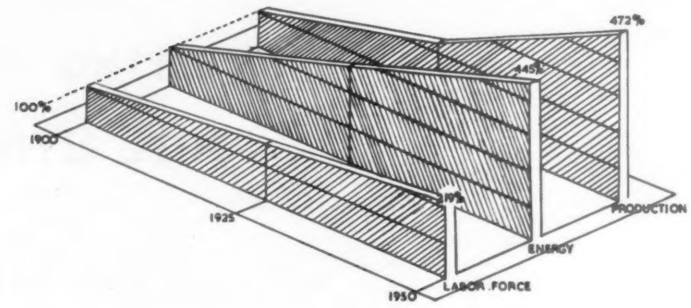


FIG. 1

double it, we must seek every possible means to improve our efficiency.

With, perhaps, the exception of coal, clay and limestone, we have no important basic raw materials which can be produced in sufficient quantities to cover the needs of the population. Consequently our prosperity depends entirely upon our ability to convert something which we import into a saleable article which we can export at a profit. Real wealth will result, not from the volume of our exports, but from the nett value of those exports left after paying for our imports. We must have industries which are efficient and which make the fullest possible use of our labour force combined with the skill of our technologists and scientists to extract as much as possible from all the raw materials available, whether home produced or imported.

Energy is no less important because we have come to take for granted that it will be available in unlimited quantities.

As industrialisation has proceeded, so the dependence on mechanical and electrical energy to replace human labour has increased. This is well illustrated by the report of the Paley Commission which surveyed the increasing use of natural resources in the United States in the half century from 1900 to 1950, and then went on to forecast how the demands might rise in the third quarter of this century. Fig. 1 shows how the labour force, industrial production and the use of energy in industry, has grown in the United States in the last half century. Setting the figure for 1900 in each case at an index value of 100, the graph shows that the labour force had increased by 1950 to 219, but that industrial production had risen much more to 472. A major reason for the rise in productivity was not hard to find. It lay in the increased use of energy by industry. Again using 100 as the index figure for 1900, by 1950 the figure for the industrial use of power reached 445. Looking into the future, the Commission expected an even sharper increase in the use of electricity between 1950 and 1975 than has occurred during the past half century, from under 400 billion kWh in 1950 to something like 1,400 billion in 1975.

Fig. 2 illustrates not only the increasing use of fuel and power but what the Paley Commission describes as the shifting pattern of U.S. energy sources. In 1900, almost all energy used in the United States was derived from coal. Water power and petroleum represented only a few per cent. of the total. By

SHIFTING PATTERN OF U.S. ENERGY SOURCES

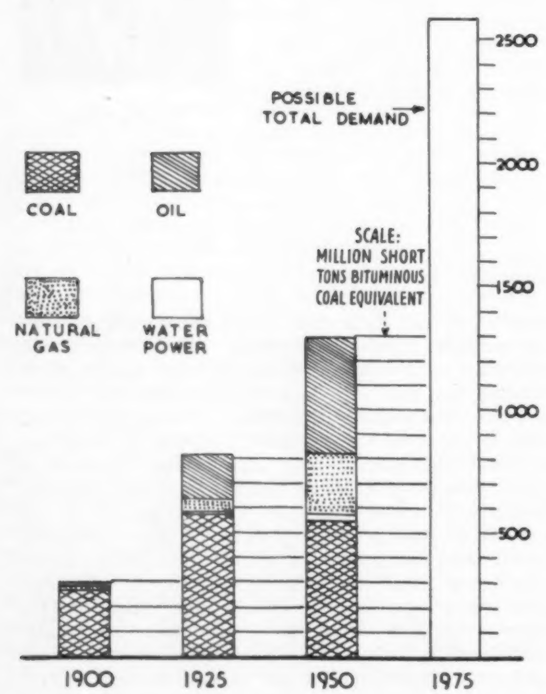


FIG. 2

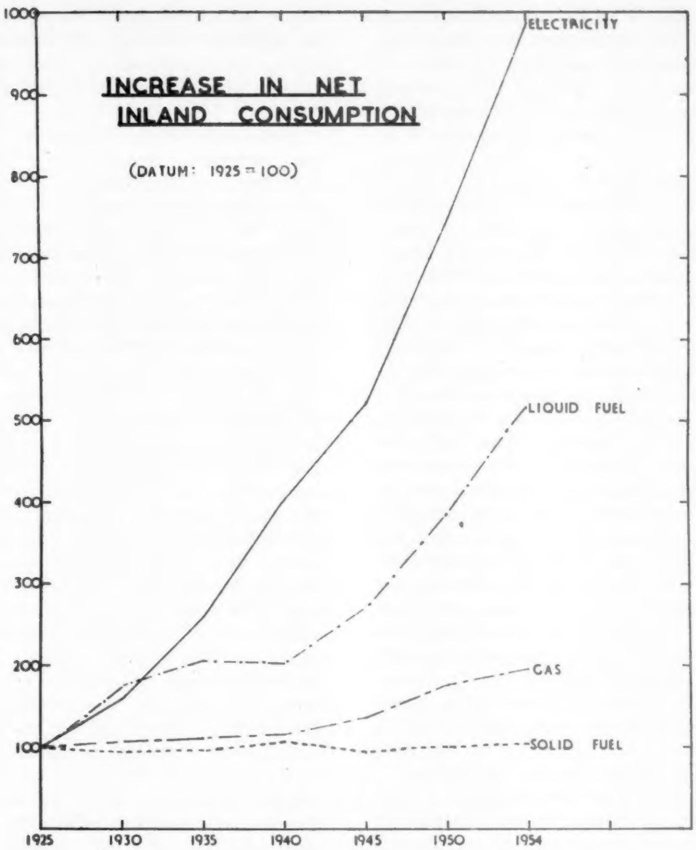


FIG. 3

1925, although coal usage had doubled, a substantial proportion of the total energy was derived from oil, from natural gas, and there had been a lesser development of hydro-electric power. By 1950, the picture had changed so greatly that coal was no longer the major source of energy. Rapid increase in the use of oil, and an even more rapid increase in that of natural gas, had brought about a diminution in the amount of coal used, despite the rise in the total demand for energy.

In Great Britain, there has been nothing like the spectacular rise in industrial productivity during the period 1900 to 1950 that the United States has enjoyed. Productivity increased in Great Britain over this half century at the rate of only about 1½% per annum as compared with a rate of 3% per annum in the United States. Total inland coal consumption increased by only one-third over the half century, and, indeed, per head of the population, it remained practically unchanged at 4 tons per annum. However, that apparently static position is somewhat misleading. It arises from a combination of causes and masks the very considerable changes that have taken place. One of the most important is the change in pattern of energy sources which has taken place in this country as well as in the United States. As Fig. 3 shows, there has been a very rapid increase in the use of the secondary, or derived sources of energy — gas and electricity — during the last 30 years, and the efficiency with which they have been produced from coal has, in turn, increased very rapidly. Again there has been a marked turnover to oil, especially since the end of the War. Even when looking at the static consumption of raw coal, we must bear in mind that since 1940, it has been held down by the rationing of domestic supplies.

It is by an ever-increasing use of energy that the U.S.A. has become the world's leading industrial nation, and if we are to compete with American goods in the world's markets, must we not aim to reach an equally high standard of productivity by the same process of substituting mechanical power for human energy ?

Much has been said and written during the last few months about the probable future fuel requirements of the world as a whole and Great Britain in particular. Estimates of requirements, at the end of twenty-five years and based on the assumption that productivity will increase at the rate of 3% per annum, vary between 300 and 410 million tons of coal, or its

equivalent in other fuels. Whilst these estimates vary so considerably, they all agree that our needs are unlikely to be met from our coal deposits and will have to be supplemented by imported fuels, mainly oil, until such time as atomic energy can supply an appreciable proportion of our energy requirements at an economic price.

Whilst long term speculation is interesting, there is a danger of losing touch with reality. Most of the estimates made are based on statistics for the years 1945 to 1954. The first four years of the period may give very misleading figures due to the aftermath of the Second World War, when numerous and complex problems had to be resolved under unparalleled conditions of industrial and social upheaval. Industry was in the throes of re-conversion from war to peace-time production, with extensive modernisation of equipment and plant at a time of acute shortage of skilled labour, materials and money. There was the uprooting and changed distribution of population consequent on war-time evacuation, national service and air-raid destruction of homes and factories which still persisted in large measure. At the same time, the pent-up desire for goods and services, following the years of doing without, was in process of unfreezing.

During 1923 the amount of coal exported was 79.3 million tons, last year the amount of coal imported was approximately 12 million tons costing £80 million which, at the present time, is more than one-and-a-half month's deficit between the value of export and imports. If the nation uses the vast amount of fuel predicted for the future, one wonders if it is really possible to close the gap in the balance of payments.

Whilst the opportunity to plan ahead should not be neglected, it is doubtful whether one can plan more than five years ahead based on estimates of anticipated growth and development. Provisional plans might be made for a further two years, but these would have to be adjusted in the light of the latest development and other considerations as time passes. Estimates of requirements beyond this period are of very doubtful value.

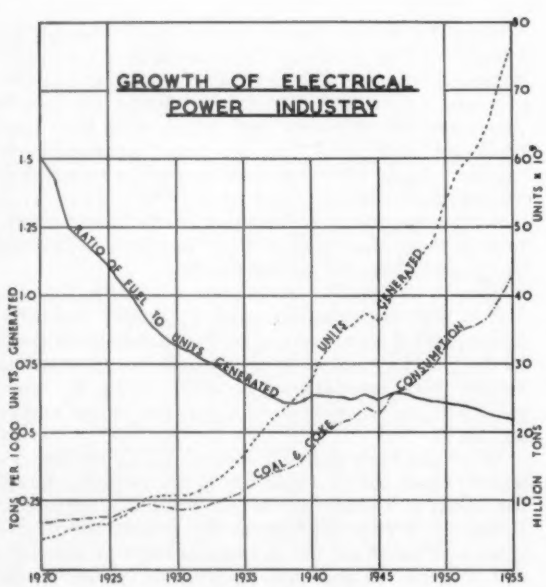


FIG. 4

Experience in the industrial field indicates that the gap between energy supply and demand can be narrowed considerably provided sufficient effort be devoted to the attainment of fuel efficiency as we now know it. Oil fuel in increasing quantities will have to be imported during the next few years, but it must be fully realised that practically every country is crying out for more fuel and power, and there is no surplus of fuel oil in the world today. It is vital that every possible effort be made to make the best possible use of our fuel and power resources to enable us to last out until an alternative source of energy is satisfactorily harnessed.

The largest single consumer of fuel in the country, and the most progressive, is the Central Electricity Authority. In 1954 they used 39.8 million tons of solid fuel and 175 thousand tons of oil to generate 71,085 million kWh, a further 2,237 million kWh being provided by means of water power. In addition, they generated 51 million kWh by destructor or waste heat plant, and purchased 153 million kWh from industry. The growth of the industry since 1920 is shown in Fig. 4, which clearly indicates the increase in consumption of solid fuel, the increase in units generated, and the fuel consumption per 1,000 units generated. From 1920 to 1939 there was a steady increase in thermal efficiency, during the period 1939 - 1948 the efficiency, based on units sent out, remained fairly static at approximately 21%, during the last seven years efficiency has again shown a steady increase, the average efficiency for 1955 being 24.14%.

The years between 1939 - 1948 were very critical in the development of the industry caused by the rapid increase in demand for power during the War years, and the 15% to 20% shortage of generating plant due to the virtual cessation of power station construction during the War. Furthermore, the heavy electrical plant industry was disorganised and manufacturing resources were inadequate to supply immediately the additional plant necessary to make good the shortage inherited from the War years, let alone new plant to meet rising demand. In the past seven years the improved thermal efficiency of operation of power stations has effected an economy of some 17.5 million tons of coal. Development over the past 35 years has been such that the coal consumption for 1955 would have been 68 million tons more had such progress not been made. This, therefore, is the contribution to date which the electricity industry has made towards closing the gap between supply and demand of fuel.

Of the total power generated, nearly 6% is used at the generating station ; the average efficiency of 24.14% quoted earlier is, of course, based on the number of units generated and not the number of units sent out. Slightly less than 90% of the units sent out are sold. The difference between units sent out and sold reflects mainly losses in transmission, but

also includes consumption in offices and showrooms and is, in some slight measure, affected by delays in reading meters.

The best operation efficiency in 1954 - 1955 was achieved by Portobello with an average efficiency of 31.53%. Stations are now being constructed which are designed for an efficiency of 37.6% with turbo generators of 200 MW, stop valve steam at 2,350 psig, and 1,050°F., with reheat temperature of 1,000°F. Three of these units will be in operation by 1960. The next upward step in steam pressures is visualised in the "super-critical" range, e.g. between 4,000 and 5,000 psig. It may well be that the average efficiency of generation in this country will reach 27% - 28% in the next five years.

American power stations which, prior to 1939, operated at a lower average efficiency than British stations, now have an efficiency some 3% higher than ours. They already have some stations operating at over 38%, and other stations are being built which are expected to operate at 41% efficiency.

We are so accustomed to the knowledge that the industrial prosperity of this country has been built up on abundant supplies of cheap coal that it is very difficult to adjust ourselves to the fact that our increased needs of energy are not going to be met from home resources and that we must turn to other sources to fill the gap during the next decade. The possibilities are : increased imports of coal and of oil ; the development of atomic energy and the more efficient use of the fuels at present available. Increased productivity at the desired rate can only be obtained by the judicious use of all three.

Atomic energy, whilst being the great hope for the future, is not likely to provide more than a very minor contribution during the next decade. The Government has announced quite ambitious and very expensive plans for the development of useful power from nuclear energy. By the end of the first development period, in 1965, twelve atomic power stations will have been brought into operation and will be making a contribution equivalent to six million tons of coal burnt in steam power stations. It is from 1965 onwards that the contribution from atomic energy will become really significant, as it is expected that this will become the source of energy for all additional requirements of electrical power. But we cannot rely on this new source of power to get us out of our difficulties in the next decade.

The importation of coal seems to create more difficulties than it cures. Last year we imported 12 million tons of coal at a cost of £80 million. Mr. R. A. Butler, when Chancellor of the Exchequer, pointed specifically to this drain on our dollar reserves when explaining the reasons for the economic crisis last year. There are also, temporarily at least, physical restrictions on further increase in our imports of coal. Our ports are constructed for the export and not for the import of coal, and additional shipping to bring more coal from America can only be found by reducing equally necessary imports of iron ore.

The greatest hope of increasing the supplies of fuel required during the next few years undoubtedly lies in the importation of oil. Consumption of gas, diesel and fuel oils has actually doubled during the past five years, and it is expected that by 1960, consumption of these oils will have increased by the equivalent of another 25 million tons of coal. We must, of course, bear in mind the fact that there is no surplus of fuel oil in the world, and every other nation is just as anxious to increase productivity as we are. Germany, for instance, itself a major coal producer is, like us, looking for greater supplies of fuel oil. We must also remember that the importation of this raw material has to be paid for by increased exports and that the price of fuel oil may rise for any one of three reasons : world competition may force an increase on a simple supply and demand basis ; an over-supply of light fractions may accompany the needed supply of fuel oil, with the result that the latter would have to bear a more realistic share of refining costs ; or new processes may increase the supply of fuel oil without actually increasing the supply of other fractions, but new processes, whatever they may be, are unlikely to leave the present price structure unchanged.

Summing up at this stage then, can we not say first that our future industrial prosperity is going to demand rapidly increasing supplies of energy; second, that after twenty years between the wars when we did not know how to make use of all the coal that we could produce, we suddenly find ourselves with inadequate supplies for our needs from our home mines and that, thirdly, the alternative of meeting the gap by imports is not only a little uncertain but also is going to create a serious strain on our economic position ?

It will be obvious to the reader that a case has been building up for paying greater attention to fuel efficiency, for making sure that we use the limited supplies of fuel available to us, whether they are indigenous or imported, to the best advantage ; in other words for "Investing in Fuel Efficiency". Before conceding that point you may well want the answer to three questions. First, are the quantities still to be saved, after all the effort that has already been put into improving the utilisation of fuel in industry, substantial ? Second, what are the basic lines of approach to the problem ? Third, can the savings be obtained at an economic cost ? In fact, is the fuel efficiency game worth the candle ? If fuel efficiency can be shown to be good business, why has it been so neglected in this country ?

What the total scope for savings is, is bound to be anyone's guess. The official committees which have devoted so much time to the use of national fuel resources have been in the best position to review all the evidence. They came to the conclusion that the potential savings to be obtained in industry were of the order of 20%.

They expected these savings to be obtained by operational improvements and by relatively minor capital expenditure. If projects such as the replacement of all industrial boiler and other plants over 30 years were carried out — and about 49% of industrial boilers fall into that age group—or power developed by condensing steam engines replaced by power generated at Central Electricity Authority stations, or if power generation by back-pressure or pass-out

TABLE 1. Range of savings possible in various industries surveyed.

INDUSTRY	SAVINGS %	
	Maximum in any works	*Average from Industry*
Brewing (including soft drinks)	49.3	23.8
Ceramics, Bricks, Tiles, Glass, Cement	50.0	15.4
Food Products	40.6	14.2
Engineering, Iron and Steel	66.9	27.5
Woollen, including Clothing	41.4	17.1
Other Textiles	55.7	13.4
Dyeing and Bleaching	34.0	20.7
Laundries and Dry Cleaners	50.0	21.3
Leather	50.0	20.5
Paper, including Printing and Stationery	41.2	15.9
Chemicals	51.5	15.0
Dairies	37.8	18.0

engines or turbines by industrial firms were carried out to the economic limit, a much higher figure would be expected, perhaps 40% - 45%.

We should not look upon the figures quoted above entirely as a reduction in the amount of fuel required to do a specific job, for we are concerned not only with saving fuel but also with increasing production. On a straight comparison basis of lb. of fuel per unit of product, 20% saving in fuel can be converted to a 25% increase in production for the same fuel consumption, whilst 40% could give 66% more production. When, however, we take into account the basic fuel requirements of a works, which are independent of the volume of production, the figures for increased production could be considerably greater than those resulting from a straight comparison.

The experience of the National Industrial Fuel Efficiency Service clearly indicates what the scope for savings still is without going into technical detail. During the past two years they have carried out nearly 800 Heat and Power Surveys. Table 1 shows the potential savings that can be achieved in a variety of industries as a result of these surveys.

The figures quoted support the potential savings estimated by the official committees. Where there has been gross neglect of fuel using equipment, whether on the side of steam and power generation or on the utilisation side of these services, it is frequently found possible to save 30% or more of the total fuel consumption. Where fuel housekeeping is reasonably good and there has been adequate technical control, the more detailed surveys show that the savings possible are, on the average, about 15%. Naturally there is great variation between industry and industry, in the attention paid to the utilisation of fuel. As a broad generalisation, the scope for economy is less in those industries in which fuel represents a major part of manufacturing costs, such as iron and steel. Again it is less in the modern and so-called scientific industries, than in the older craft industries where, of course, equipment tends to be much older.

TABLE 2.
Variation between best and worst yields per ton of coal consumed in various industries.

INDUSTRY	HIGHEST YIELD %	AVERAGE YIELD %	LOWEST YIELD %
Cement	4.28	3.29	2.5
Biscuits	20.0	2.0	1.0
Building Bricks (Intermittent kilns)	16.7	5.0	3.7
Building Bricks (Continuous kilns)	44.7	8.8	4.8
Silica and Basic Refractories (Intermittent kilns)	3.1	1.5	1.1
Grain Drying	224.0	80.0	56.0
Laundry	5.0	1.0	0.4
Beer ... ...barrels	112.0	40.0	18.5
Brewers Malt	7.5	6.0	4.2
Iron and Steel, Rolling and Re-Rolling of ingots	15.0	4.0	1.0
Whiting	14.0	13.0	12.0

However, in almost every industry there is a staggering difference in the fuel consumption per unit of production between one factory and another. Examples from a number of industries are shown in Table 2.

In making comparisons of firms within a given industrial group there is, of course, serious danger that you cannot be sure of comparing like with like in the product. To take beer, for example, the normal fuel consumption per unit of production depends very much on the proportion of bottled beer to draught beer that the brewery is turning out. Even if one makes allowance for this, it would be rash to assert that all the bottled or all the draught beers in the country are identical. However, such differences are not sufficient to account for the enormous variations in fuel efficiency that are shown in the Table and they demonstrate the scope there is for reducing the consumption merely by bringing the worst practice up to the level of the average.

This brings us to the basic lines of approach to the problem, which must be considered under two headings, short term and long term. Taking them in the reverse order, ultimate fuel efficiency demands that all plant and equipment must be designed, constructed, installed, operated and maintained correctly, and be replaced before it reaches the museum piece stage. This requires extensive and intensive training schemes at all levels—management, fuel technologists, designers, engineers, plant operatives, stokers, etc., coupled with plant manufacturing facilities and heavy capital expenditure for the replacement of obsolete and inefficient equipment.

The short term policy can be put into operation immediately and will gradually merge into the long term plan. There are very few concerns that could not reduce their fuel consumption by at least 10% with very little effort and negligible expenditure by such simple things as improved or planned maintenance, training of operatives, thermostatic control of equipment and structural or plant insulation.

Education and Training

There is a serious lack of knowledge on the boiler-house and furnace floors where so much fuel can be wasted when an ill-trained man, or a man with no training at all, is set to work firing by hand. Every effort should be made to ensure that boiler and furnace operators are trained. It goes without saying that this instruction must be as practical as possible. If it is to be acceptable to the operator, it must give him the opportunity of obtaining a certificate of competence from a recognised authority. Such authorities, quite understandably, will not make awards, unless the courses of study meet certain minimum requirements. Yet that conflicts with the need that these particular courses should be as brief as possible.

For fifteen years, great efforts have been made to train boiler operators at technical colleges up and down the country. For all that has been achieved, no one will deny that the results, in terms of numbers trained, have been disappointing. The one gleam of hope is the system developed by the National Coal Board for their own firemen, that of bringing the training to the men by instruction on site, backed by home study material.

N.I.F.E.S. offered this system to general industry for the first time last autumn, and have no doubt that it represents the best opportunity of saving more coal quickly. It is interesting to note that about 2,000 boiler operators will sit for the City & Guilds B.O.C. examination, this year.

Maintenance of Plant

Much has been written about the savings that can be achieved by attention to such items as leakages from pipe flanges, safety valves blowing, or by-passed, defective insulation, air infiltration through boiler settings, badly fitting furnace doors and dampers, choked filters, etc.

Lack of attention to these items, and many others which can be called to mind, does waste an enormous amount of fuel. Nevertheless, these items should not be considered under the heading of fuel efficiency, but under that of defective maintenance.

Boiler Plant

Statistics produced by the Ministry of Fuel and Power, as a result of their Survey of Potentialities for Back-Pressure Generation of Power, indicate that the average evaporation in steam plants at works using over 2,000 tons of fuel per annum is 6.7 lb. per lb. of fuel. The same survey indicates that over 49% of the boilers in use are over 30 years old. Assuming an average gross C.V. of 11,500 B.T.U. per lb. for the coal used, it gives an average boiler plant efficiency of 63% which leaves much to be desired.

Table 3 gives an indication of the savings that can be achieved in the boiler house by the various improvements which can be made. It should be clearly understood that these figures have been obtained from wide experience of many types of boiler installations. They cannot be applied as such to any particular plant, but they do give some idea of the savings which can be expected.

Power Generation

Industries fall into three categories, namely, the large steam users, whose steam demand is always so great that they can generate more than sufficient power for their needs; those whose power and steam requirements are normally balanced; and those whose power requirements are greater than could be met by back-pressure generating plant. There is a constant flow of factories from the first category to the second, and from the second to the third. The more efficient a factory becomes, on the steam utilisation side, the more certainly and speedily does it pass into the third category. The reasons for this are quite simple; every

TABLE 3. **Savings obtainable in boiler plants.**

IMPROVEMENT	SAVING AS % OF TOTAL FUEL USED
Use of feed pump exhaust for feed heating or reconditioning of feed pump	2–7
Replacement of steam jets for fire bar cooling ...	2–8
Overhaul of safety valves to prevent blowing ...	Up to 8
Recovery of heat from blowdown or reduction of blowdown	Up to 3
Improved firing	Up to 20
Installation of economisers	Up to 12
Descaling of boilers	Up to 7
Reduction of air infiltration	Up to 3
Prevention of internal leakage in brickwork ...	Up to 7
Avoidance of by-passing of economisers	Up to 7
Insulation and covering of feed and storage tanks	Up to 4

economy in the steam used or heat conserved in the factory processes reduces the amount of steam available for power generation. Most technical improvements reduce the factory heat demand and increase the power demand. Almost every labour-saving improvement also increases the power demand.

A large factory in the first or second category can generate power with about 40% of the coal used by a modern condensing power plant by passing the steam on its way to the heating process through an engine or turbine. Even a modest engine in a small factory need only use about 66% of the coal burnt per unit generated by a condensing plant.

Factories in the third category must either purchase their deficiency from public supply or generate their own power by condensing part of their exhaust steam. There are many old-established factories in this category which generate their own power as a matter of custom. Unless factories are using the exhaust from their engines or turbines, they may, in extreme cases, be using two or three times as much coal as the large condensing power plants.

The amount of power that can be generated from a given weight of steam may be increased by raising the initial pressure, by superheating or by decreasing the back-pressure, but the benefit at the high pressure end is very much less than that obtainable by an equal pressure decrease at the low pressure end.

There are many industries which, in addition to using low pressure steam for process purposes, also

TABLE 4. **Savings obtainable in Process Plant.**

IMPROVEMENT	Saving as % of steam consumption in unit
Covering of dye-vats	30–53
Effluent recovery from dye-vats	30–40
Insulation of bleaching kiers	Up to 7
Replacement of external heat exchanger by pump circulation round bleaching kiers	Up to 9.5
Mechanical removal of water, hydro-extractors	Up to 12
Air recirculation and humidity control of textile dryers	Up to 35
Vapour recovery from brewing coppers ...	Up to 48
Condensate recovery and return to hot well ...	Up to 10
Use of flash steam	Up to 15
Thermostatic control of unit heaters	Up to 16
Effluent recovery from cake washers, rayon industry	Up to 60
Thermostatic control of steam used for direct injection to tanks, vats, etc.	Up to 30
Reduction of steam pressure	Up to 7

require very large quantities of hot water, for instance, carpets, dyeing, rayon, laundry, etc. This hot water can often be made available in conjunction with power generation, by making use of a proportion of the exhaust steam or by continuous circulation of water required for process purposes through the condenser.

Table 4 summarises the savings that have been achieved by modification to process plant by various methods. The figures given do not represent either the maximum or the average to be expected by any particular plant modification.

The problem of obtaining a high degree of fuel efficiency is not entirely an engineering one. There are numerous text-books and papers available that show exactly what can be done, and there are well qualified engineers who are prepared to discuss problems at any time. The real problem is to persuade management to get expenditure on fuel supervised as carefully as they do other manufacturing expenses. Management insist on the close control of raw materials, stores, stationery and even stamps, but when it comes to the control of fuel, heat and power, it is left only too often in the hands of unskilled operatives.

Although large fuel savings have been shown as possible, this does not necessarily reflect on the capabilities of the engineering staff; only too often is the engineer required to provide the essential services and then find that he has no control whatsoever over their usage. In order to increase productivity and reduce fuel wastage, Directors and Managers must ensure the closest possible liaison and co-operation between engineering and production staff.

Can the savings mentioned be obtained at an economic cost? Is there a danger that in our enthusiasm to save fuel we are advocating measures which will not produce a satisfactory return on capital expenditure? Many industrialists immediately assume that it is necessary to spend large sums of money on new plants before reasonable fuel savings can be achieved. Experience has shown that this is not correct. Of the works surveyed, a large percentage of the savings can be achieved by operational control and planned maintenance with relatively little expenditure. As a general rule, seven years for repayment of capital is the maximum that is recommended and frequently capital expenditure can be recovered from the gross value of the fuel saved within three years. The laws of supply and demand will inevitably make all fuels more costly even than they are now, so any fuel saving equipment which proves economic on present day prices is bound to show even greater economies over the life of the plant.

N.I.F.E.S. brochure "Fuel Efficiency Pays" illustrates a hypothetical, but unrealistic, case in which the benefits to be obtained are worked out in full. The argument in that brochure is related to the Government Loan Scheme whereby money is made available for fuel efficiency schemes on terms free of interest for the first two years, and thereafter at commercial rates of interest with repayment over a period of up to 20 years.

Up to the end of March, 1956 the total amount of loans granted was just over £2.25 m. ; 42% of this sum was for schemes concerned with oil conversions, the average capital expenditure being £5.7 per ton of coal released. The average capital expenditure required to save one ton of fuel by fuel efficiency methods, such as the installation of mechanical stokers, insulation, economiser, heat-exchangers, back-pressure engines or turbines, etc., was approximately £13. This figure confirms the view expressed earlier that capital expenditure can frequently be recovered from the gross value of fuel saved within 3 years.

The above figures refer only to the proposals which have qualified for the Government Loan Scheme. These can be regarded as typical of the possibilities in small or medium-sized firms, but of course the potential is very much greater than the savings so far realised.

It is quite interesting to try to compare the economics of fuel efficiency in industry with that of other schemes of capital expenditure, in support of which the claim is made that, among other advantages, they will bring relief to the coal industry; for example, with the construction of new power stations, which now needs less than 1 lb. of coal to generate one unit of electricity as compared with the present average system of about 1.25 lb./kWh; with the plan for modernisation of the British Railways by electrification and dieselisation; and with the cost of developing nuclear power as announced in a recent White Paper.

The difficulty in trying to compare these schemes is that none of them have coal saving as their sole objective, so that one could argue for ever as to what part of the capital expenditure should be taken into consideration. This, of course, is also true of fuel efficiency schemes, which more often than not yield as much in improved productivity as in reduced fuel costs.

The figure for power stations is based on statements made in the Seven Year Record 1948-55, that the result of installing more efficient plant since vesting date has been to reduce coal consumption by 17½ million tons from what would otherwise have been required. To achieve this, nearly 7¾ m. kW of new plant has been installed at a cost of some £462 m. This gives a capital expenditure of £26.4 per ton of coal saved.

The capital cost figure for the railways is taken from the British Transport Commission's recent report on modernisation. It represents the proposed expenditure on locomotives for electric or diesel traction, plus the civil engineering work involved but not the costs of providing additional power stations. The estimate for coal saving comes from Spencer's Paper and as it is based on the assumption of 100% electrification, it errs on the generous side. The capital cost per ton of coal saved works out at £43.

The figures for power from nuclear energy—£50 per ton saved—are based on the current White Paper

plans. If credit is given for the fact that these nuclear power stations will make the construction of conventionally-fired power stations unnecessary, then the capital cost can be reduced to £30 per ton of coal saved.

If fuel efficiency is such good business, why has it been so neglected in this country?

Part of the answer may be that management is not indifferent but that it is insufficient. There are so many problems that beset those in charge of industry today that, in the average concern, there is just not enough managerial time or technical experience to go around. Consequently the available time tends to be concentrated on the production line at the expense of the services. If £10,000 worth of the firm's product was regularly spilt on the factory floor, management would be on to it. £10,000 worth of fuel wasted in the boilerhouse or in steam utilisation more easily escapes detection.

Another part of the answer is that fuel using equipment is generally robust and long-lived. By far the greater part of such equipment in British industry today was installed in those pre-war days, when coal was not only cheap but so abundant that we were devoting our energies to finding new ways of using it up. The efficiency of the plant, therefore, reflects the economics of a vanished era. It is perhaps understandable that the limited capital available in the years immediately after the war should have been used first for improving production methods. There was always the chance that if the fuel shortage was ignored, it would go away.

N.I.F.E.S. are finding, however, that the attitude of industry towards fuel efficiency is changing, partly no doubt as the result of the sharp increase in cost of fuel, and partly due to the fear that with the decline in coal production coupled with the desire for increased productivity within industry, there may be insufficient fuel to meet the needs of industry. Table 5 gives an index of how industry's demand for N.I.F.E.S. services has increased during the two years which the organisation has been operating.

One repeatedly hears of the decline of manpower in the mining industry which has dropped since 1939 by 62,300. In 1939 the percentage of absenteeism was just under 7%; it is now 12.2% so that the virtual loss of manpower is not 62,300 but 94,700. If absenteeism were reduced to 10% it would be equivalent to recruiting a further 17,360 miners and increasing coal production by 5.17 million tons. If the pre-war figure of 7% absenteeism were achieved, it would be equivalent to recruiting a further 39,500 miners and increasing coal production by 11.8 million tons. Is this effort too much to ask or expect?

In the next ten years the N.C.B. plan to spend £1,000 million, at current prices, on development of the mines and hope to increase output from 221 million tons to 240 million tons, i.e., by 8.6%. Can we afford not to invest a fraction of this capital on industrial fuel efficiency measures? Is there any point in spending vast amounts on producing or importing more fuel simply to meet a large demand created by wasteful practices?

Fuel efficiency must play an increasing part in the solution of this problem of finding the supplies of energy to support the country's industrial development. We cannot attain our objective without "Investing in Fuel Efficiency".

TABLE 5.

	ENGINEER DAYS AVAILABLE	SURVEYS MADE	REGULAR SERVICE AGREEMENTS SIGNED	VISITS MADE UNDER FREE ADVISORY SERVICE
1954 2nd Quarter	4285	27		1535
3rd Quarter	6201	53	10	2211
4th Quarter	7105	102	26	2113
1955 1st Quarter	7830	145	42	1837
2nd Quarter	8159	97	39	1745
3rd Quarter	8114	71	35	1933
4th Quarter	9331	149	74	1888
1956 1st Quarter	10762	178	108	2014

INVESTING IN BETTER FACTORY DESIGN, CONSTRUCTION AND LAYOUT

by DONALD TEMPLE MYERS, Dip.Arch., Dip.T.P., A.R.I.B.A.

Mr. Myers is an architect in private practice and a consultant architect.

THERE is still a great deal we need to know about the general requirements for the design of buildings for specific industries, their comparative suitabilities and operating costs.

Any course of betterment naturally demands a detailed knowledge of the problems involved, problems which vary from industry to industry. So that in such a short Paper, even with full knowledge, one could only indicate the signposts which point the way to better factory design. Consequently one cannot elaborate upon the merits and demerits of various types of construction for they would appear to vary with the industry, the time and the place. Before we can have correctly functioning factories as normal representatives of every industry, we need — **more knowledge,** gained from a very detailed and up-to-date study of industry. There must be a ready source of information upon the conditioning factors of various industries at the disposal of the men who design for them, so that no time is wasted in unnecessary individual research. For today, in its highly specialised forms, industry can only function properly in specialised buildings which are themselves half machine.

This is not to say that out of the specialised needs of individual industries we shall not, by research, find a great deal of common ground thus facilitating a greater economy in cost and time by permitting standardisation of more parts of the building. This has occurred in America and is partly responsible for their amazingly quick construction times. The Americans discovered that many specialised and diverse functions could operate in the same basic type of building, developed from a need for adaptability from war to peace production. They have produced standardisation, by research, out of specialisation.

We could, in turn, perhaps develop a series of building types, suitable for our needs in this country, which would be specialised in their flexibility, that is to say, in their ability to absorb production changes. And surely this a basic need for the better factory today. But first we need the knowledge and this need I intend to discuss in more detail later.

Suffice it to say that this Paper is built upon indications of common needs of industry which could be rationalised by a research programme capable of benefiting industry as a whole.

Any such programme would have to take automation into account, for if full automation can give almost 100% production efficiency, then logically, a better factory could be one which is progressing towards automation. We can expect certain changes in the architecture of both factory and office ; for automation has made of the factory a conscious

mechanism, allied in its functioning to the human body. It has a brain, nerves and eyes.

The covering to the human process is a specialised one ; the result of the processes within and the conditions imposed from without. It gives a degree of protection, acts as a filter, and gives enclosure to vital organs. So also then, would the covering to the automatic factory be a specialised process, the result of conditions imposed from within and without. It is, therefore, considered essential that we align any study of factory design with a consideration of the effects of automation so that we are fully capable of utilising its vast potentialities.

There is today a great need for technological integration, and we must remember that new times, new methods, whether in factory or office, sometimes call for different architectural solutions.

PROCESS + BUILDING = PRODUCTION TOOL

We no longer think of process on the one hand and building on the other. The building is, or should be, the result of the conditions imposed by the manufacturing process and a crystallisation of the thoughts of the many specialists involved in its design. The result of this is a fusion of building and process.

We know that if the building does not work then the process cannot operate at maximum efficiency and the result is a faltering production tool. Thus, the building has a key part to play in production, for considerations of siting and transport, initial building costs, and maintenance, are all reflected in the final price of a product.

The Better Factory and its Importance Today

Our aim must be to produce industrial buildings which will work as hard as the machines they house in enabling us to turn out finished goods economically. Thus, the better factory would appear to be a synthesis of the ultimate in machinery and the building which will contain that machinery in the most adequate way.

It is well, at this stage of our economic and social history, that we, as a nation, do not under-estimate the urgency of such a concern. For already we feel the growing pressure of foreign competition. And, with the advent of automation, which will probably integrate building and machine to their ultimate stage, many of the present under-developed countries will be able to take their place in the lists of industrial rivalry. Moreover, the use of nuclear energy will obviate another former deterrent to industrialisation — lack of conventional fuel supplies.

Thus, if we are to continue to compete on world markets and enjoy any trading advantages leading to an increased standard of living, it is essential that the buildings of industry make a direct contribution to increased efficiency of production. We must strip down and examine the costs of our produce, and architects have their part to play in ensuring the economy and efficiency of the buildings which house the machines.

The study of factory design is the history of industry and is a composite of several subjects, each of which provides material for a Paper on its own, particularly when requirements differ from industry to industry and often within the same industry. It is, then, necessary to give a sense of pattern and cohesion and build a framework of common needs upon which to discuss industry's past mistakes and future requirements.

The common need is **space,** and industry, in general, suffers from :-

> lack of space ;
> *or*
> mal-use of space.

Space, in architecture, is not an abstract quantity ; rather is it the only reality. The architect's prime function is held to be that of an analyst of space. In designing a building, we think in terms of the eventual use of that building and it is this use which enables us to place on paper a few tentative lines indicating the confines of the building or the limits of space. These limits, the walls, floors and roof, have a job to do in relation to that space, for they enclose it and preserve its environment. The space becomes the medium through which we achieve the heat, light and sound qualities of the building. By talking of space, we refer to space and its elements, heat, light and sound and we think of it as a living thing which we create from the pattern of needs of a process or function ; by structure we achieve it, and by enclosure do we preserve it. Thus, architecture becomes the creative manipulation of space and its confinement by technology.

Thus, our factory buildings become units of space designed around the differing requirements of individual industries, their production areas, storage areas, and office areas. For the purposes of this Paper we can apply such an analysis of space to each of the related stages in the manufacturing process, knowing that it is only by an increased awareness of the true nature of space and its elements that we can hope to provide an industry functioning at its full potential.

Thus, we can expect that the better factory *must* make a more intelligent and realistic use of space and will have :-

1. A production space engineered for efficient running with preplanned maintenance, flexibility of production and expansion designed into the building.
2. A storage space designed closely around the movement of material yet permitting flexibility.
3. An office space designed around the exchange of information rather than pieces of paper.
4. A welfare space which is the whole factory complex and not merely the recreation areas and amenities.
5. An enclosure to the space which will work to maintain whatever climatic conditions are necessary for a process and so cut down heating and cooling bills, and which will possibly make greater use of standardisation and prefabrication.

6. A site chosen for both present and future needs.
7. Generally, economical buildings which will go up on schedule, and, once up, will require little maintenance.

However, to discuss, in such limited space and time, so complex a subject as factory design one must be selective and deal only with fundamentals. Consequently I have either omitted or dealt lightly with those of the above sections of an industrial organism which have either been treated extensively elsewhere or which form a separate subject. I refer specifically to Welfare and the work of the Industrial Welfare Society, Lighting Service Bureau and The British Colour Council and office buildings which form the basis of an individual study.

PRODUCTION

'The client's analysis of the problem must be the first move towards its solution.' — *Kahn*.

The shape of the space, and certain of its characteristics, depend upon the individual industry and its requirements. We can, therefore, only survey points which have a general application to industry as a whole.

The major issue is that industry never seems to have enough space. New machines are developed and have to be crammed into existing inflexible production areas which were not originally designed for them. Positioning of such units is naturally circumscribed and once such a move is made within a production area a host of attendant troubles, such as the following, may arise :-

(a) faulty positioning of secondary machines ;
(b) irregular supply of raw materials ;
(c) frequent buffers to absorb irregularity of production ;
(d) broken or hyphenated production lines ;
(e) crossed circulation ;
(f) inadequate heights, spans and load bearing capacity ;
(g) inadequate and badly laid down services.

It is unlikely that we have any one industry suffering from all of these complaints. They can, however, occur in any industry which attempts to operate within inadequate space.

Therefore, designing for an industry means creating flexible space specifically for that industry, in such a way that it is allowed to expand, or contract properly, and readjust itself easily and economically to meet the changing demands of the age.

Designing for Flexibility

Flexibility incorporated in the design means visualising changes in production which will require either new machines or a relocation of old, and/or the future expansion of the building to accommodate increased production.

Some of the large car plants in the U.S.A. have virtually grown out of this need for flexibility, for car design has always been subject to the external trends of taste and the market. The manufacturers demanded factories which could be gutted from end to end whenever it became necessary to revamp the production layout. The main plant quite often consisted of only one building, a huge structure with a flexible positioning of wiring points in a vast, column free production area over which was jacked a flat roof, acres in extent. Machines could be relocated and coupled up with the minimum of interference from the confines of the building.

The main elements constituting flexibility are roofs, floors and services. Walls, which should be flexible in that they can be taken down in sections and reused, are considered under " Enclosure ".

Roofs. If, in designing to meet future demands, the precise pattern of development cannot be visualised clearly, then the basic need may be for a production area as free as possible from obstructions. Thus the roof becomes an increasingly important element of design, for by adopting large span systems of construction we can free the production area of the customary forest of columns, each of which sterilises from 9 - 16 sq. ft. of working floor area. Designing in steel over large spans, we are, to a great extent, limited to pitched roofs and deep chord trusses. Within the depth of such roofs we can house power and service leads which would formerly have impeded changes on the floor. A strengthening of the bottom chord of these trusses would allow for future overhead conveyors and handling equipment at any point. If this heavier loading is designed into the truss, the cost of the extra material is negligible. If, however, such roofs need to be modified later, the cost will be multiplied many times, for as with most jobs, it is the handling and not the material which costs the money. Moreover, even if it were possible to adapt roofs for future loads, it could perhaps involve a temporary stoppage of production.

Floors. Adequate flexibility in floor construction entails making provision for the easy relocation of old or a laying down of new machines. Frequently, machines have had to be torn bodily from their holding bolts, they have then been re-positioned and concreted in once more and the old area of floor hacked up and relaid. Difficulties have been encountered when the existing floor at the new location has not been strong enough to take the load, thus necessitating new machine foundations.

If the pattern of production change can be confined to a certain area, then that area could have adequate foundations for any machine shift. Another system would be to place continuous strip foundations under the production line, or at various points to which moves may be contemplated (Fig. 1).

But I feel that this is not really tackling the problem at source. If we decide that flexibility is a good thing, then it must be a complete flexibility which does not cease at roof and walls and services. It must extend into the actual floor itself. There must surely be a more civilised method of planning for the relocation of large machine units than by having to hack up concrete.

Fig. 1.
All presses are on a continuous foundation strip designed to take machine loads at any point. This makes it possible to move presses if necessary to keep pace with production developments. Use of 60 ft. trusses made it possible to reduce the total number of interior columns in this 120 ft. × 240 ft. area to a total of three, thus, further facilitating any movement and re-alignment of machinery. Since the photograph was taken the factory has been taken over by a manufacturer of major household appliances who has found it ideally adapted to his operations. The former owner made automobile equipment.

(Photograph by permission of The Austin Company, Engineers and Builders, U.SA.)

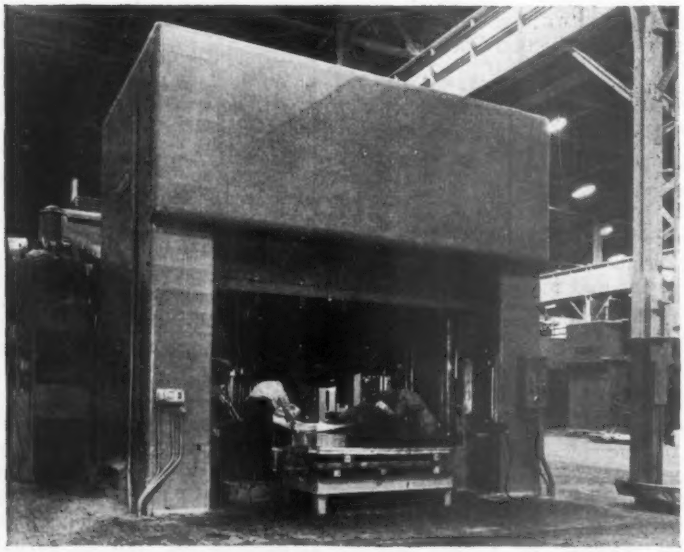


Fig. 2.
Nine Mile Press Plant — showing 130-inch, 1,100-ton Torque Drive Toggle (Hamilton) Press.

Fig. 3.
Nine Mile Press Plant — basement under typical Press Bay, showing concrete supporting piers and main longitudinal beams on each side. View also shows cross beams for supporting grillage floor. The beams are part of the system of structural supports for presses that permits maximum flexibility in press location, both for initial installation and future changes. Lower part of large press in background.

Perhaps a pointer in the right direction is afforded by the interesting example of built-in flexibility at the Chrysler press plant in the U.S.A. Before redesign these presses had most of their moving parts above floor level and were set in deep pit foundations which made relocation almost impossible. Now, only the actual metal-forming sections are above the floor with the moving parts in a service basement below floor level, providing readily accessible servicing space. Thus relocation simply means taking up the surrounding oak flooring slabs and craning the press in sections to the new anchorage (Figs. 2 and 3).

In certain industries, to obtain complete flexibility in the positioning of machines the whole floor could be formed of a suspended framework. The areas required for the machinery would be left open to the basement under, with the other areas paved by precast slabs. The cost of this flexibility would be offset by the provision of the basement for the servicing of the machinery and maintenance.

Services. The increasing control exercised over some processes has placed greater emphasis upon the functioning of the mechanical equipment and services which can together absorb almost half of the cost of the building.

For full flexibility of process, then, these services should be as amenable to future changes as the machines themselves.

We can ensure this adaptability by leaving the production floor virtually free of built-in service points and placing the service leads either in the roof space or in an open basement under the production floor.

Roof Space. A standard power distribution system in continuous ducting can be slotted into the roof space so that machines can be plugged in at any point. There is then no question of available power points freezing a layout, or power leads trailing over the floor (Fig. 4).

The roof space may also be designed to take all the heating and ventilating equipment, which may be assembled on the floor on platforms and then raised up into the roof. This eliminates working on scaffolding in the roof space and effects economies in labour. In one plant in America, $3,000 per unit of three is said to have been saved by this method.

An increasing number of industries are finding some measure of controlled interior conditions indispensable for a correctly functioning process. Even where the process itself does not need it, air cooling is often necessary to counteract the heat from the machines and the higher intensities of lighting.

In America, where the demand is much greater, there is a high degree of standardisation of conditioning equipment; in some instances it is provided on a 'controlled climate by stages' plan (see caption to Fig. 7). Perhaps, with the advent of automation, controlled conditions of operation will be so essential that standardisation will be practicable in this country.

Fig. 4.
An overhead system of flexible wiring provides power for both the production machinery and the building utilities (pumps, fans, unit heaters, etc.). To make any additional machine connections or changes in layout of various departments it is necessary only to disconnect the fused plug-in device at the 'bus' (black conduit shown in photograph) exposed overhead. The main factory lighting is also taken from the bus-way system through small transformers mounted high on the columns. Clark Equpt. Coy., Jackson, Mich., U.S.A.

(Photograph by permission of Albert Kahn Associated Architects and Engineers Inc., Detroit, Mich., U.S.A.)

Underfloor. An underfloor system of conduit and piping provides ready access and changeability for future machine connections. In the Western Electric Company's electronic plant in U.S.A., a packed wood maple floor gives access for direct connection to distribution lines. This grid of services includes distribution lines for compressed air, illuminating gas, oxygen, hydrogen, nitrogen, steam and water. Each is suspended from the steel floor beams and is painted a distinctive colour (Fig. 5).

Automation

Some degree of automation will appear in most industries from process to metal-working and assembly. It will probably occur in simple stages, shop by shop, until, in some cases, a complete production system is automated. However, there will be the instances when automation is considered initially, with the architect briefed for the design of suitable buildings to accommodate what amounts to an automatic factory.

The most significant fact which emerges from a study of automation and the buildings concerned is that with the closing up of machine processes and the consequent cut down in circulation space, there is an average floor space economy of 50%. Thus, the production buildings may be smaller in area (Fig. 6).

There may not be the necessity for the vast, enclosed spaces which we now associate with industry; spaces both difficult to span economically and expensive to heat and condition. If such spans were indeed reduced it could mean thinner chord roofs of portal frames, in welded steel, alloy, or concrete. This would effect an immediate saving on walling, for a large span truss must be deep to fulfil its function. The difference between depth of a portal frame and a truss could be as much as 6 ft., so that if we take the example of a factory with a floor area of 100,000 sq. ft. we will easily see the cubic content involved.

Flexibility. The question of flexibility within an automated production line is complex and interesting, and it is difficult to imagine production changes being either frequent or fundamental. The immense capital involved in the design and provision of automated machinery makes it essential that a large and reliable market is reasonably assured. However, it would be against the laws of nature if changes were not subsequently required, and I think it must be accepted

Fig. 5.
(Photograph by permission of The Austin Company, Engineers and Builders, U.S.A.)

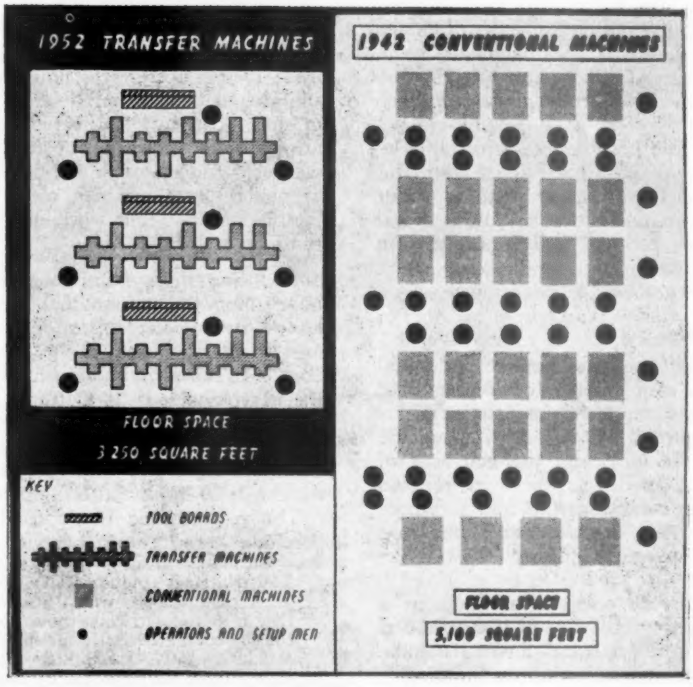


Fig. 6.
This analysis by the Ford Motor Company shows the floor space economies resulting from the adoption of transfer machines for a particular job.

(Diagram by permission of 'American Machinist'.)

that provision for flexibility in the production line will be built into the machinery. (This will, of course, require great forethought, almost to a degree of clairvoyancy, and I am only grateful that this is not the responsibility of the architect.)

A degree of flexibility is incorporated in some of the existing examples of automated machinery. In the automated line for the production of turbo-compound aircraft engines at the Wood Ridge plant of the Curtiss-Wright Aircraft Corporation in America, different models can be produced with the same equipment and still more powerful future models can be assembled using the same technique.

Furthermore, in 1946, John Sargrove perfected ECME, the machine which turned out radio sets at the rate of one every twenty seconds. He came up against and solved this basic problem of the automated factory — flexibility. His machine will take product change in that a number of different circuits can be turned out with only minor variations in the mechanics of the apparatus. Each processing stage is housed in a separate cabinet, which can be removed from the line or altered as variations in the circuit design are called for.

When changes in an automated line become necessary, conveyors or particular transfer machines could perhaps be adjusted to take the new machine unit. Thus the automated line would vary little in its overall length.

It might, therefore, be anticipated that a great proportion of the flexibility required for an automated factory would be provided by the machinery itself, in which case, flexibility of production would cease to have such control over the architectural approach to the factory.

In my summary of the possible effects of automation, however, I hope to show that, apart from this negation, it will give a most positive impetus to our industrial architecture and allow us architectural solutions as completely rational and as exciting in design as the machine solution.

Design of the Enclosure

Today the design of the enclosure to industrial buildings is no longer a simple matter of keeping wind and weather from the machines, for many of our processes demand rigorous control of atmospheric conditions within the factory, and the materials of which the enclosure is made can help to perform these functions. These conditions fall into the three main categories of adequate thermal insulation, good sound levels, and well designed lighting.

Thermal Insulation. Every year, in this country, a fortune is spent on heating bills due to ill-considered heating programmes, and an equal fortune can be saved by correct thermal insulation of our buildings*. Even the most elementary forms of applied insulation can effect considerable savings, as in the case of one particular firm which saved £1,500 in their first winter, by the mere addition of a cheap insulating material. They then insulated their stores and cut their fuel bill by another £1,300.

Even better results can be obtained if thermal insulation can be designed into the building, for thermal calculations made whilst the building is still in embryonic shape can often result in a safe reduction in the scale of heating plant.

The enclosure itself must exercise thermal control and act as a balance between outside and inside temperatures, determining the rate of heat exchange. It should neither transmit inner heat to the outside nor outer conditions to the inside. If this were always effected with total efficiency, then stepped-up heating or cooling programmes would become unnecessary.

In the interests of heating, lighting, and ventilating, the influences upon size and position of windows are absolutely conflicting. The solution has often been one of compromise with perhaps the usual accompanying lack of merit.

In industrial buildings, natural lighting and ventilation are difficult to control and the desirability of incorporating views into the production area is most debatable. Windows in walls can light only to a certain depth, after which to light by natural means we must use roof lights, such as North lighting or monitor construction. The latter tends to be even more thermally extravagant than strip wall lighting, as the diagram will show (Fig. 7). Furthermore windows need to be cleaned and maintained. Outside they are accessible, but far more dirt collects on the inside where they are often less easily reached.

The most powerful argument against resorting to artificial lighting and ventilation, and in consequence the scrapping of windows, is that of psychology. However, it is interesting to note that in Sweden, where the greater part of her defence programme is underground, a survey** indicated that there had been no adverse effect on the health and comfort of the worker. Indeed, with the measures of control now at our disposal, we can often preserve more satisfactory and constant working conditions by artificial, than by natural means.

Sound Insulation. Opinions differ on the effect of noise upon the human make-up. However, a well-known neurologist *** found that brain pressure increased by as much as 400% during sudden, loud noise. It causes irritability and 'undue excitation of the nervous system'. Constant, loud noise not only has a direct bearing upon general conduct but also strictly limits powers of concentration. Yet very little attention has been given to preserving sonic standards in industrial buildings.

The major sonic function of the enclosure is to preclude sound transmission, both in and out of a

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* The National Industrial Fuel Efficiency Service has many case histories which bear out the savings possible. One in particular, concerns a firm in Scotland who had considered the necessity for installing a new boiler, cost £15,000. An N.I.F.E.S. survey showed that the purchase of a second boiler would be unnecessary if the factory roof were insulated and the rate of air charge restricted. Cost of insulation was £25,000 ; a reduction in the company's fuel bill of £5,700 per annum, in addition to the saving of a second boiler.

** Joint investigation held by Swedish Confederation of Employers and Trade Unions.

***Dr. Foster Kennedy.

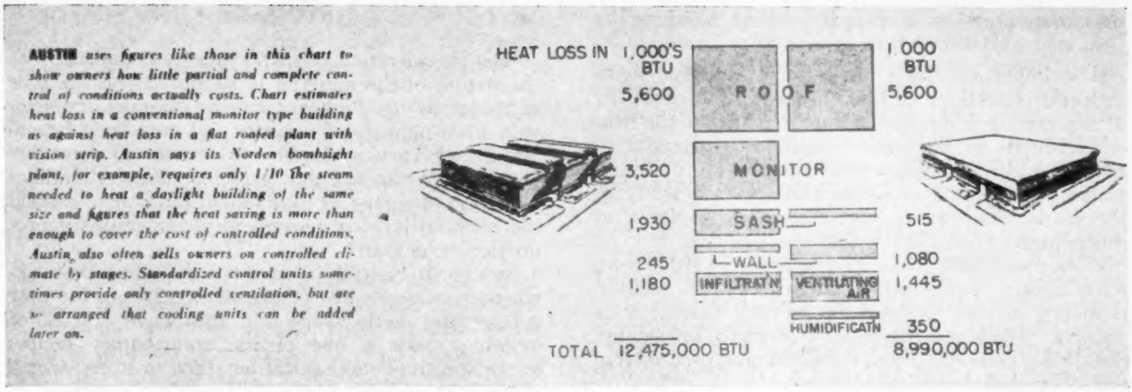


Fig. 7.

Austin — *Austin Coy., U.S.A.* (*Diagram by permission of 'Architectural Forum', U S.A.*)

building. In industry, we are mainly concerned with reducing the noise from the process to a bearable level internally, and ensuring that whatever noise there remains shuttling around after treatment does not escape to cause nuisance to other sections of the factory or to surrounding development.

Consequently, I would recommend that acoustics be given early design consideration, for an acoustical engineer can suggest and incorporate precautions against nuisances such as undue transmitted noise from air conditioning equipment and machine vibration.

It would be even better, of course, if the machines themselves could be given greater acoustic considerations, thus stopping internal noise at source.

Floors depend mainly upon construction for their insulating performance, owing to floor sound being one of impact from trolleys, fork-lift trucks and reverberation from presses. A good, sound insulating floor does, then, depend upon separating or floating the various elements so as to break the diaphragmatic action induced by impact. Thus we insert non-conductive materials where necessary. This, too, can only rightly be considered at the very inception of the scheme where it can become an integral feature of the design.

Similarly early attention can perhaps be given to isolating noisy processes from the rest of the factory group.

For an adequate sound treatment of any building, its shape is important. In most cases in industry, such a degree of acoustic consideration would be impracticable. However, the long, narrow buildings which follow straight production lines, and which we generally associate with industry, behave like organ pipes and set up a high degree of resonance, particularly if (as sometimes happens in industry) the end walls are parallel. Thus, some form of baffle break-up might prove efficacious but for the services, overhead equipment, etc., which would render such a proposition extremely difficult, except in isolated cases. In some types of building, however, it may be possible to think in terms of baffles which could fold back into the walls when not in use and which would only project a sufficient distance to break up the tunnel effect of the interior.

To prevent noise from the factory causing local nuisance it is necessary, once again, to consider windows. Experiments in broadcasting have shown that double glazing of different thicknesses, separated by a wedge-shaped air space, can break the diaphragmatic action since the two weights of glass do not respond to the same frequency.

If double glazing were considered from the thermal standpoint, no doubt it could be designed to fulfil an additional acoustic function.

Our basic requirements from the enclosure are adequate thermal insulation, sound insulation and protection. We may or may not need windows. However, for industrial buildings we also need speed of erection and a freedom from weather nuisance. Thus we imply an enclosure which reduces the number of trades engaged upon it, is speedily erected, and which has its own built-in thermal and sound properties; in short, a prefabricated enclosure. Preferably it would be in panels which could be easily handled by two men, or alternatively large enough to make the use of mechanical equipment economical. It should be attractive in appearance, should require little maintenance, should weather well and be 100% re-usable. Ideally it should be possible to substitute standard double glazed windows for any section of panel to allow greater flexibility. Perhaps we may eventually arrive at the stage when we have windows during the warm (?) summer months, for psychological reasons, and substitute them quite simply for standard cladding panels during the definite winter months. There would not necessarily need to be windows in the whole of a factory wall but perhaps one or two, in position where they could trap and diffuse the most sunlight.

Such panels hung on to a structural frame would be easily demountable for purposes of alteration or

expansion and would permit ease of handling by relatively unskilled labour.

The important thing about such walling systems in sealed or semi-sealed buildings is that, theoretically at any rate, it should be possible to calculate the heat requirements of the process and heat potential of the machines, lighting, etc., allied with optimum working conditions, mix the whole with a study of the yearly temperatures in the area and so arrive at the requisite conditions within the building.

A sandwich wall could then be made to order from standardised insulating, cladding, and acoustic elements, to give as near the correct conditions as possible. Mechanical methods of heating, or cooling, could then be reduced to a minimum and used merely for occasional boosting.

Built up panel walling systems have been used to a great extent in America and there are variations considered suitable for our climate in this country. The extremes of ranges of temperature which occur in America have led to panels which have built-in condensation seals.

The Consolidated Vultee Plant in Fort Worth, Texas, has such a light-weight metal faced shell wall only 6″ in thickness which provides heat and vapour control, sound absorption and light reflection. In this case the sandwich wall had to be built around internal air conditioning needs, necessary for both worker comfort and the process. It had to conserve energy and preserve a balance between the cool interior temperature and the blistering Southern sun outside. Fortunately, in this country, our requirements are a little more modest.

These panel walls are usually thinner than those using traditional materials. Consequently a building can be erected upon a given site possessing a greater internal usable space than a building using more traditional walling materials.

Automation and the Enclosure

With a greatly reduced number of productive workers, a windowless plant, with all its advantages, can surely be utilised. Excellent heat retention qualities and studied lighting, calculated to do its precise job generally and locally, would be substituted. Moreover, the amount of overhead handling equipment, which certain automated processes may require, would tend to obscure a great deal of natural roof lighting.

In designing the enclosure to an automatic factory, sound precautions will be of tremendous importance. It is highly probable that some factories will be in 24 hour operation. Therefore, if industry is to pursue its good neighbour policy, some efficient means of preventing machine noise from escaping to the exterior must be adopted. Once again the desirability of windows must be reconsidered. We may also have to think in terms of sound-cum-thermal locks at entrances and exits.

Similarly, we should consider the question of light nuisance, and perhaps favour sealed factories which do not roar through the night with all lights ablaze.

STORAGE

The consideration of such spaces is bound up with the nature of the material to be stored and the type of materials handling envisaged. Storage problems vary from industry to industry and have been rationalised with varying degrees of success. However, in general, one can say that very few storage buildings have been designed as they should have been, around the essential forward movement of materials for production or despatch.

Storage is basically a materials handling problem, whether stores lie idle or are in circulation, for they still occupy costly space and equipment. Lack of building space is one of the contributory factors to the spread of mechanical handling in stores, which is generally taken to effect economies in **money,** in **time,** and in **manpower.** I would take it yet one stage further and use it to provide economies in storage **space.**

The Situation Today

Space costs money; it has to be enclosed, heated and perhaps even conditioned. Yet today, one sees storage buildings that are huge empty barns twice as high as they need be, with a floor area of which 50%, maybe 60%, is taken up by fork-lift circulation and column areas. Some buildings are of shapes, such as U or L, which immediately restrict smoothly flowing operations, and all too often expansion is impossible. The floors are inferior in quality and surface thickness, and heavy fork-lift traffic soon makes this quite obvious. The vast perimeter walling of such buildings has to be maintained, and the windows, often unsuitably positioned, have to be cleaned. Stores are racked in front of them, thus obscuring whatever light may have filtered through. Illumination presents its own problem and heating usually consists of ineffectual unit heaters blowing hot air into the place at points about twenty feet above where it can do any good.

One wonders why such buildings are tolerated. The initial fault is that quite often a manufacturer buys a cheap sectional building, developed for a multitude of purposes, and never realises that such a structure is frequently unsuitable and requires a considerable outlay on heating and maintenance.

We should never under-estimate the importance of the storage building and the part it plays in manufacturing. For it can permit an easy flow of goods or it can cause a dam. In purely physical area it is often the greatest single unit of the factory layout, far exceeding the combined footage of production area, amenities, etc. It cannot be contained within *any* building, for it is a specialised function. The failure to realise this has been the ruination of more than one promising enterprise and is the potential ruin of quite a few more.

More thought must be given to the rationalisation of storage. Cubic space must be made to work. Circulation space must be cut down. Then, and only then, will architects be able to design around the stores functions, buildings which are economical and efficient in every way.

Moreover, we must remember that the smaller the building, the more structural solutions there are usually open to us and the greater the site economy.

We have then either to :—

cut down circulation space and divise some simple means of storing cubically;

or

reduce the height of the building to the maximum operative height of a fork-lift truck;

or

develop completely automatic selection and disposition of goods from storage and design the building around such an automated function.

What is required from the Storage Building. Flexibility of production and expansion of production has its repercussions upon the storage area. Storage should represent equal flexibility, and any increase should be in direct proportion to the increase in factory space.

If no mechanised storage is envisaged, then the required space must be as free as possible from any of the limitations, imposed by the building, which may eventually circumscribe any desired change in storage pattern.

The shape of a building to take material handling operations is important. The square is cheaper than a rectangle in that there is less wall needed for a given cubage and footage. Moreover, a well proportioned store warehouse has a favourable effect upon labour costs. For, as the ration of the length to the width increases, so do material hauls become more protracted. A prominent American firm of industrial architects are of the opinion that building proportions should not exceed 3 - 1 and that an L or U shaped building should be avoided at all costs.

Narrow sites, permitting only longitudinal expansion, can bring the ratio to more than 4 - 1 and, as expansion takes place, so labour costs will rise, until finally the manufacturer will be rolled out of his warehouse by soaring labour costs as business expands.

Ways to reduce material hauls to a minimum should be our concern, and the first way is to have a compact building. I would say that neither the square nor the circle have been given sufficient attention in this respect.

The buildings should be designed around the pallet load and its spacing and around the stacking pattern and aisles for fork lift trucks. A consideration of the number of pallets in a given area will signify the method to be used and whether the emphasis should be on space or movement, i.e., straight line stacking or block stacking. Thus, bearing in mind other considerations of roofing economy, the suitable bay can be designed around these factors.

Straight Line Stacking. This requires the minimum fork lift activity but adequate space is essential as is also freedom from the restrictions imposed by the elements of the building. Stanchions, tie beams of roof trusses, doors, lifts, and of course, walls, influence the position of all stacks and hence the ultimate layout.

The basic need is, therefore, a free open space which should be of the correct cube to be economical in operation. It should be regarded merely as an umbrella over the storage area and should have the greatest span consistent with economy. It should be possible to expand the building if it becomes necessary. Thus, ideally, the walls should be sectional and of dry, unit construction.

Block Stacking. Minimum space but adequate fork lift movement is needed with this pattern of storage. Thus, it is necessary to ensure that the amount of space devoted to fork lift truck circulation does not affect the economy of the building. Generally aisles less than 4 ft. in width and greater than 14 ft. are costly and in all, circulation should not represent much greater than 35% of floor area*.

When thinking in terms of fork lift trucks it is essential to consider desired load plus counterpoise load. This effective load doubling can have an operative effect upon the floor loading of storage buildings, in particular, multi-storey structures.

It is not so essential to have such clear open spaces for storage if block stacking is intended permanently, for most of the blocks can be built around the stanchions. Thus a certain building economy may result owing to the nominal spans permitting standard construction.

Diagonal Stacking. This is only practicable for stacking in a long, narrow, existing building and is seldom advantageous as a method in itself.

The use of windows in these stores, other than some form of roof lighting, is a doubtful necessity. They cause heat losses and the stacking patterns prevent any overall lighting.

Similarly, it is important that the artificial lighting of storage buildings be designed bearing in mind the storage patterns intended. Otherwise the stacks can prevent a good general level of illumination.

Earlier in this section I mentioned several of the prevalent ailments of stores buildings. In conclusion, I feel justified in making specific and pointed reference to four of the most common. They are, inadequate heating, poor fire resistance, unsuitable placing of supervisory accommodation and unserviceable floor construction.

Adequate Heating. The same conditions that apply to the design of the enclosure for the production buildings apply to storage. Instead of erecting a building and then trying to heat it, as is so often the case, the heat requirements of the material to be stored should be ascertained, and a suitable heat figure determined for a full store and a half-empty store. Then materials for the enclosure can be determined and the correct quantity of booster heating installed.

In general, methods of heating in stores are inadequate. High stacking prohibits normal heat circulation so the tendency is to place unit hot air

* Curtis H. Barker. "Industrial Materials Handling."

blowers on the stanchions above the stacks. The result is a band of warm air which does not circulate, but remains static as shown by the broad band of black dust which extends round the stanchions at this hot air height. In certain cases, it may be much more appropriate to instal some form of radiant heating in a position which will permit convectional circulation of warm air.

Fire Resistance. Qualities of fire resistance should be designed into the building as a means of localising the outspread of fire. Full reliance should not be placed upon the customary sprinkler system, for high stacking of stores can render it inadequate. Unvented, continuous roofs can cause mushrooming heat and smoke to build up an uncontrollable conflagration, as in 1953 at the 1,500,000 sq. ft. General Motors plant at Livonia, U.S.A. Therefore, as a ready means of keeping fires small and manageable, it is advisable that some form of thermostatically controlled venting be designed into the roofs of large storage buildings, with the provision of fire curtains to give further protection.

In certain American factories plastic vapour barriers, which do not add fuel to the fire, have been used on top of the metal roof decks. Heat retardant paint which bubbles up into a vermicular, non-combustible and insulating coating has also come into use.

Supervisory Accommodation. A frequent cause of complaint amongst stores personnel is that their accommodation is not in the most suitable position. It is often at the extreme end of a long building and tends to make their work rather difficult. They cannot exercise supervision over the whole store on account of the stacks impeding vision. Some form of central stores receipt and staff accommodation might well be considered.

Floors. I wish to make specific reference to the flooring of stores and warehouses and emphasise the dangers of any false economy in its construction. Primarily it has to stand up to a considerable beating from fork lift trucks. Concrete is an extremely difficult material to repair properly, even if such repairs can be done without having to re-route storage. Any expansion joints must be very carefully detailed and constructed, otherwise they will tend to have their edges crushed and chipped.

Present Trends

In some industries, particularly assembly, the production building itself is being used, to some extent, as a store. Components are in constant circulation on overhead tracks and come into the process where and when needed, whilst further supplies of components are in stillages on trailers parked in the open air outside the factory. Thus storage space may be provided by adding height to the production building and allowing trailer parking facilities to supersede a covered storage building.

The increased speed of mechanised processes demands that there be a closer integration between stores and production. It is logical that materials handling links, whether horizontal or vertical, should be reduced to a minimum. And it is in connection with this increased speed of production that we should consider potential storage facets of automation, so that we may, in keeping with industry's axiom of maximum flexibility of building, provide structures which would facilitate a turn-over to automation.

The Influence of Automation. The high speed and increased productivity of automated processes will enforce a correspondingly high degree of mechanisation of storage.

We may, in fact, consider automatic disposition and selection from storage. The warehouse will have to be as automated as the production line and the storage flow will be a logical extension of the production flow. We shall design the storage facilities around spaces determined by the movement patterns of mechanical methods of materials handling.

Limitations. The production levels forecast for automated processes indicate greater efficiency and capacity of stores handling. With the stocks of raw materials required for a long run and the accumulation of finished goods many existing stores, and even sites, would prove totally inadequate. Furthermore, such vast storage would represent a freezing of capital which could well be employed elsewhere.

With automation, therefore, storage efficiency becomes of the greatest importance, and storage areas must eventually represent the briefest possible pause both between incoming and circulating raw materials and receipt and despatch of finished goods. They will no longer be stagnant but will become feed reservoirs through which will pass a constant flow of goods.

Ultimate automation, where taped instructions will set into motion a chain of events leading to the completely automatic conversion of raw materials into a finished product, wrapped, labelled and addressed, will be possible only so long as the supply of raw materials keeps pace with instructions. This presupposes a highly efficient transport system.

These, then, are our terms of reference. Automation cannot function with a faltering mechanisation of supply. Around these new storage systems we shall design our stores buildings.

LOCATION

The location of the industry, i.e., the examination of factors conditioning the initial choice of site, is invariably held to be outside the scope of the architect. However, the ultimate efficiency and economy of a factory may be imperilled by the choice of a site, consequently the architect would appear to have his part to play in the early discussions.

By applying the factors of production, land, labour and capital to a particular proposed process, a manufacturer may be able to narrow his location needs down to a certain area. If his proposals meet with the necessary approvals, it is possible that he may have the opportunity of selecting any one of a number of sites.

At this stage, if not earlier, I would emphasise the desirability of calling in the architect upon the scheme. Thus he has the opportunity of seeing the growth of the project and is then in a position to suggest possible economies from the very start. This early collaboration between client and architect, in which the requirements of the process are first studied without reference to buildings at all, is infinitely preferable to the architect having to drop buildings over a layout already prepared by the client. His full knowledge of the client's requirements enables him to advise on the site conditions, such as the position of site access, the bearing capacity of the soil, etc., as well as the demands of future development, expansion and flexibility mentioned previously.

The Effect of Automation upon the Location of Industry

When thinking in terms of the future, automation immediately comes to mind, for it appears that it will have a considerable effect upon the location of industry. The operative factors are the decreased dependency upon an existing labour force, the economies in floor space possible with automated production, and the effect on transportation.

Reduced Labour Force. By freeing an industry from dependency upon an existing labour force, an immeasurably greater number of sites are opened up. It may be possible to site industries on a more logical basis, where they can operate at optimum efficiency.

Decreased Floor Space. In the industries examined by David Osborn in his 'Geographical features of the Automation of Industry' prepared for the University of Chicago, there is a mean floor space reduction of 59%. Woollard cites a possible 50%, so that industrial space needs may be halved. An additional factor influencing floor space is that brought about by the reduced labour force, for it will possibly indicate a reduction in staff amenities and facilities. Shorter shift hours will have a bearing on the size and nature of canteen facilities. It is also possible that employee car space will be reduced, either through redeployment of labour or a greater number of shorter shifts.

Transportation. Speeded up industrial processes will have to be served by highly efficient transport supplying a constant, steady flow of raw materials and providing adequate facilities for the collection of finished goods. This implies siting where transport hauls of raw materials or finished goods are reduced to a minimum, as for example at or near the source of raw materials.

It is possible that certain raw material supplies will be carried finally in conveyor or pipe lines, and so free road and rail transport for purposes for which they are more suitable.

Even so, we can imagine our road, rail, river and perhaps canal arteries to be heavily loaded in future. They must be efficient to enable our highly mechanised factories to maintain constant production and keep only token stocks of raw materials. We must, therefore, recognise this and realise that in this country there are complex transportation problems. We have, with 18.4 vehicles to the mile, the highest road density in the world. The road will, indeed, be our major problem for it carries a far greater percentage of our annual freight than any other form of transport *. Excessive overheads due to transport disruptions and delays can relentlessly help to price us out of overseas markets.

Today we are aware that there are few technical obstacles in the way of the automatic factory ; it is largely a matter of when and where. We may find, however, that competition will force us into an earlier acceptance of the completely automatic factory. Yet we, who can, as John Diebold has stated, become the automation workshop of the world, may find our economic progress strangled, our industries idling because of broken lifelines. I would plead that we do not consider our factories as being isolated in space. They depend for their continuance upon adequate communications, and transportation must be regarded as an equal partner with automation.

Results of Automation. Smaller factories, not dependent to such a great extent upon existing labour forces, will possibly open up a new series of sites permitting both increased centralisation and extreme decentralisation.

New industrial patterns may emerge ; cognate industries will tend to group more closely for the above 'transportation' reasons. We may be able to site small industries in districts which have so far been unsuitable or inaccessible for industry and of no use for farming. A key factor in siting for certain industries will be the disposal of increased quantities of trade effluent and a supply of water for processing sufficient to keep pace with higher production levels.

Hitherto our town planning schemes have catered largely for the relocation of existing industry from central areas. The aim has been to find an increased area of industrial land for a reduced quantum of industry on the assumption that the land requirements of industry have increased.

We might well ask if this is true any longer and, because industry is a major influence upon our planning development, we can expect that these different 'location' factors will eventually have a considerable effect upon regional planning.

Recommendations

In Britain we cannot afford to be profligate with our use of land. It is essential that we consider the influences of automation so that our industries may be sited accordingly. Perhaps we shall have to proceed initially by creating a balance between present siting needs of a factory and its requirements when that process is automated, in order that it may continue to be in a suitable position and in a good relationship with any cognate industries.

* Freight transport in Great Britain. (Basic Road Statistics, 1955.) Survey carried out by M.O.T. in 1952.

Tons carried:

Road	900,000,000 tons.
Rail	300,000,000 tons.
Inland Waterways ...	10,000,000 tons.
Coastal Shipping ...	40,000,000 tons.

One thing is certain, we should think ahead for automation, otherwise we shall jeopardise the work we have already done in attempting to plan our country.

SITE LAYOUT

Full efficiency cannot be either expected or obtained from the industrial buildings without an efficient site layout.

This may appear rather obvious, yet the number of sites on which one finds ill-assorted groups of buildings, with little or no transport circulation space around them, makes one wonder. They are often laid out in a way which prohibits future development; consequently such firms contemplating expansion have little choice but to start building anew upon a different site.

Increased productivity, bringing more traffic to the site, invariably catches up with these site limitations; hence the importance of choosing initially a site which will measure up to future expansion needs. Furthermore, such a site must be laid out so as to minimise future disruptions during a comprehensive development by ensuring adequate future access to the site and circulation within it.

The key to ease of expansion is to estimate future power needs and place the power house in such a position that it can serve all eventual development. If the final pattern of expansion cannot be predicted with any degree of certainty, it may b_ better to string power leads overhead on gantrys, in which case they can be altered with greater freedom than when underground.

One development which has grown out of all proportion is the need for employee car park space. This is seldom adequate in existing factories and it is doubtful whether sufficient space can be allocated to those still in the planning stage.

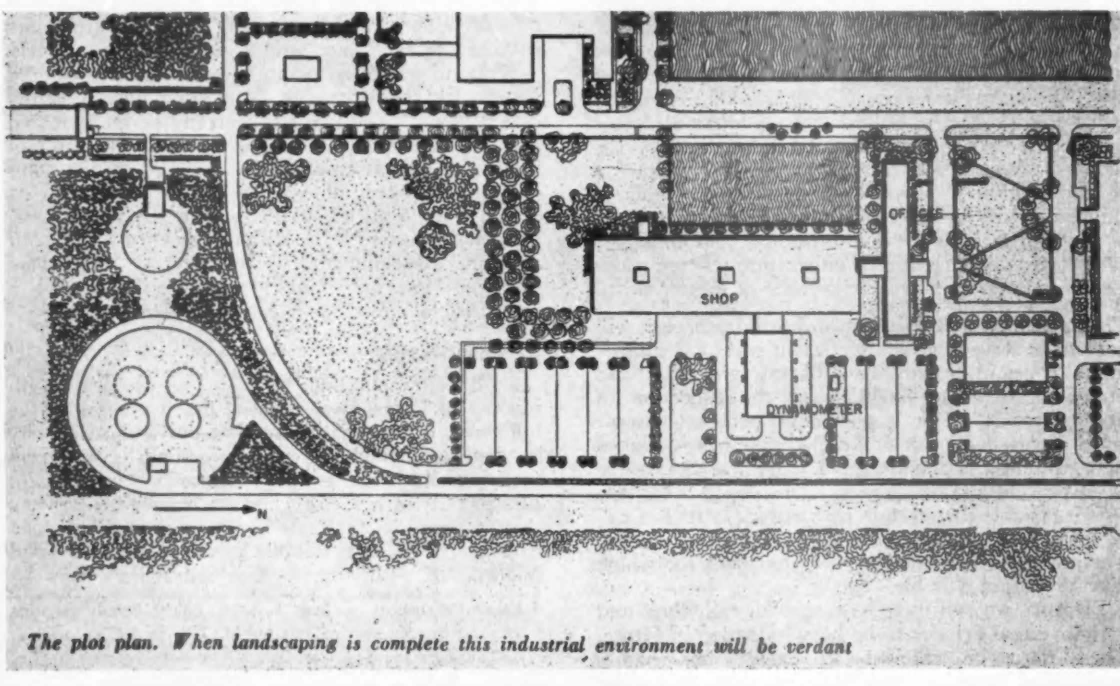
A suitable position for the car park may have a considerable effect upon the location of employee cloak and locker rooms, so as to make access to the plant more direct. Works buses drive through a ground floor tunnel right inside a drug manufacturing plant in America. The number of minutes saved for each of the 1,000 workers amounts to thousands of dollars in manufacturing costs.

Aesthetics of Site Layout

There is no reason why we should apologise for introducing into the harsh realities of industry that indefinable quality which produces a result greater than the sum of the individual parts—a consideration of aesthetics.

The lesson to be learnt is that a site can be adequate and functional, and yet be so planned that it gives emphasis to the buildings, shows them in their best light and makes a unity of buildings which may, by very reason of their function, have to be in a set relationship to one another.

Certain sites would permit landscaping with well chosen planting, pools, and differences in levels (Fig. 8).



The plot plan. When landscaping is complete this industrial environment will be verdant

Fig. 8.
This General Motors Technical Center near Detroit, U.S.A., has been called the 'Industrial Versailles'.
(Diagram by permission of 'Architectural Forum', U.S.A.)

Yet we commonly associate industry with dirty buildings and heaps of rubbish lying about in the yards. Industry can make a virile, forceful contribution to more pleasant surroundings, not only for the workers, but for those who may have to look upon it every day from their homes. Industrial equipment, once prudishly hidden away, is now painted silver and exposed boldly to the elements. It echoes our contemporary, direct approach to design and, being somewhat expressive of our age, we tend to find it aesthetically pleasing. Architects, in particular, enthuse over the huge gleaming tanks, distilleries and regenerators which we associate with the various processing industries.

Even such superb examples of design as these need to be relieved by a conscious and human-scale planning of surroundings and site, and indeed, would lose nothing in the process. Moreover, an industry which makes a visual contribution to the appearance of a neighbourhood would be appreciated both by the workers and those who live nearby. Therefore, a consideration of what can be done to make an industry a better neighbour visually, and more pleasing aesthetically, is a sound investment.

It is always hard to tell where comes the dividing line between these aesthetic considerations and the hard practicalities of industrial life. I sometimes wonder if there is one at all. For if work surroundings are pleasant, and have been imaginatively laid out, other things being equal, productivity must surely be improved.

Focal points in this consideration of aesthetics often seem to be mirrored in the road approach, the night architecture and the air view of the factories.

Road Approach. The road approach to factories is of great importance. It is from this that visitors and passing traffic can gain their first impressions of the factory. A well laid out access leading to striking buildings with surroundings consciously designed for them can give a layman great confidence in the product turned out by such a place.

Night Architecture. Some factories may be running twenty-four hours out of twenty-four ; others may just light up for advertisement's sake. Nevertheless, showing the factory complex at its best from the road or rail routes which fringe most factories, can be of tremendous importance.

The things one sees as one passes such places must be carefully selected and perhaps floodlit. Well laid out buildings with carefully designed surroundings can do more for a firm than thirty-foot high Neon lighting. For an impression of beauty, in what we have come to regard as an unlikely place, coupled with tasteful advertisement, lingers longer than a garish display.

Air View. In these days of heavy and increasing air transport, most industries would benefit from a well designed plan layout which would be distinctive from the air both by night and day. A layout which could rationalise the tired sprawl of the normal industrial group would stand out boldly from the customary industrial squalor, in which blackened buildings sit untidily upon littered acres of oily concrete, without a tree or a bird within miles.

The Influence of Automation on Site Layout

1. Increased productivity will mean a proportionately stepped-up transport turnround and we must pay great attention to traffic routing within the site in order to avoid circulation bottlenecks, particularly if access is limited.
   It is almost certain that nearby landing facilities for freighter aircraft will have to be provided.
2. Smaller size of factories employing full automation will possibly indicate more space initially available for an imaginative site layout.
3. The type and nature of the buildings on the site may change. Stores may no longer be a separate building, but may be closely integrated with production. Work conditions under the new labour requirements may alter. In years to come an increased number of shorter shifts may rule out normal canteen buildings. The facilities they supplied would be taken over by vending equipment on the factory floor. Offices would be in direct electronic contact with the machines and would be more essentially a part of manufacturing ; possibly being incorporated into the manufacturing area. They would be smaller in area than their present-day counterparts owing to the mechanisation of clerical work. Thus, the factory and its ancillary buildings would tend to be superseded by one building, which could be likened to the human body having built in power supply, storage, production and accounting. A factory would then emerge as a complete industrial organism, half-building, half-machine.

A SUMMARY

At this stage I should like to summarise.

I have discussed, and I hope stressed, the desirability of designing flexibility into our industrial buildings. I have suggested lines of thought, from strengthening roof trusses to having prefabricated panel walls, and floors built as an adaptable feature of the building. I would emphasise that these are suggestions, the merit and demerit of which would be ascertained by adequate research into individual industries.

I have also surveyed, very briefly, the possible effects of automation upon our industrial buildings, their siting, planning and so forth. In many instances automation will appear on the scale of a small production change, an experiment which, if successful, will be continued. In some cases the continuation of such an experiment will almost turn the building inside out or else will mean an entirely new building. In other words, for a building to be adaptable to automation, it may require a greater degree of flexibility than previously thought possible ; a degree in which virtually nothing in the building is in-

capable of adaptation to the new conditions. This flexibility must be considered in terms of size and construction.

We are accustomed to think of flexibility for expansion, but with automation we may expect space economies of up to 50%, so that our factories may have to be flexible in that they may be reduced in size. For a building to be profitably reduceable, it should be designed and built so that its parts can be sold or re-erected elsewhere. This suggests a co-ordination of parts which would be generally acceptable to industry as a whole, and which must, therefore, be designed on a modular or standardised basis. To stand up to a series of changes, the parts would have to be durable, probably prefabricated under controlled conditions, and definitely designed for ease of transportation.

Flexibility of size depends upon the degree of flexibility we can incorporate into the construction. We may find that to automate a process within an existing building we shall require a certain height clearance from the machines to the underside of the trusses to accommodate overhead supply routes, which would feed the machines and would also provide bank stocks. If such clearances cannot be fully determined, because of variables such as machines and routes which have still to be designed, then a roof which could be both adjusted in height and yet be strong enough to take overhead traffic at any point, would be desirable. In an ordinary truss we can simply strengthen the lower chord to take the extra weight; but in order to incorporate adjustability into the roof designs, I would suggest that we might think in terms of combining the lift slab technique with space frame construction.

The lift slab method, originated in America, entails pouring a slab of concrete for floor or roof on the ground, around the columns which will eventually support it. This slab is finally raised to the required position by means of hydraulic jacks on the columns and is then cleated into place (Fig. 9).

The space frame is a built-up roof in which forces act in three directions, and is capable of spans completely outside the possibilities of normal post and lintel construction. It would behave as rigidly as the slab of concrete and could probably be raised completely assembled, with air conditioning ducts and services already in place, in the same manner as the concrete slab. Assembly on the ground would greatly cheapen construction by eliminating scaffolding and construction equipment. Any air-conditioning equipment, etc., would, of course, have to be sufficiently

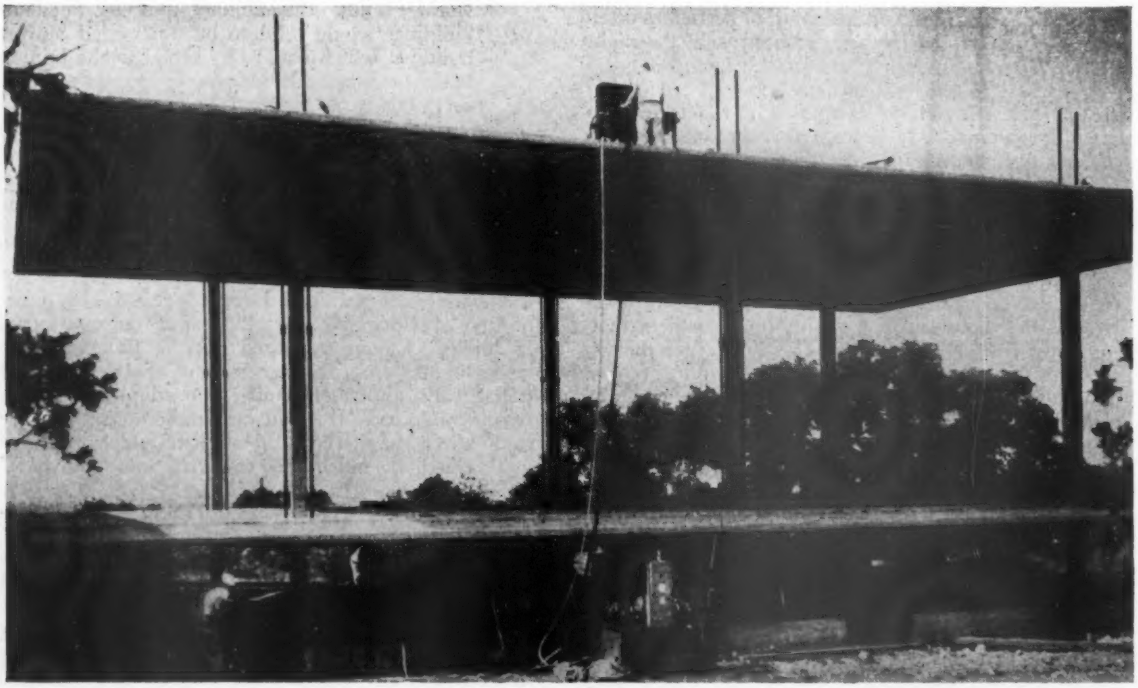


Fig. 9.
Lift slab method: Roof in position; first floor slab being hoisted. Trinity College, San Antonio, U.S.A.
(Reproduced by permission of 'Architects' Journal'.)

flexible in design to cater for the increased cubic content (Fig. 10).

The columns could be of the maximum desired height. However, the roof need not be raised to the full limit of these columns until the extra height became necessary, when hydraulic jacks could again be coupled up and the roof raised. There is one instance in the U.S.A. of a small building erected on the lift slab principle, having a roof slab and an auxiliary slab bedded down on top of it to be brought into use when a first floor becomes necessary. Thus, stage lifting would appear to be practicable.

The idea of preplanned maintenance, so essential to an automatic factory, will probably be taken one stage further and actually designed into the building. It could be by means as simple as the type of under-machine service basement discussed in 'production', which would enable maintenance to be carried out whilst the machinery was running. Swarf, or other waste channels running in the direction of the machines, could be underslung into this basement.

A variation of the maintenance pit would be to place the machines on a steel grid above ground, on what would amount to a huge machine chassis, the underside of which would be the service area.

Walls could be constructed of panels giving adequate thermal and sound insulation, and designed for ease of handling by unskilled labour for replacement and expansion purposes.

These transitional automatic factories will, eventually, give way to those which will be designed specifically as automatic factories. I have mentioned previously, in each section, the circumstances which, in my opinion, will influence their design and I should now like to survey them collectively.

1. A quick, efficient transport turn-round will be vital.

Ideally, reliable transport, whether by conveyors or normal road and rail means, operating at the same speed as the process, would virtually eliminate storage areas.

As a progressive move towards cutting down transportation cost-time, automatic factories may tend to group in a close cognate relationship, thus forming small industrial estates. This being so, it may then be more economical to have one central packaging and despatch store, to avoid the necessity for a number of small finished stores, and so simplify traffic circulation within the site. Similarly, there could be one central mechanised accounting section and possibly central communal facilities, medical rooms, etc., forming part of this warehouse.

2. Automation will provide floor space economies.

Automatic factories will probably be smaller, in plan area at least, than their present-day counterparts due to the economies derived from the better utilisation of space resulting from closing up machine processes and cutting down circulation.

3. Materials handling links should be reduced to a minimum.

The design of the building can help. For if we continue to think of space economies produced by automation we shall think cubically and place raw material storage directly above production.

4. Preplanned maintenance.

There should be ready access to the machines at all times with no necessity for interference with production. Service trenches and pits must be so designed that maintenance engineers may inspect frequently and work comfortably, furthermore they should be

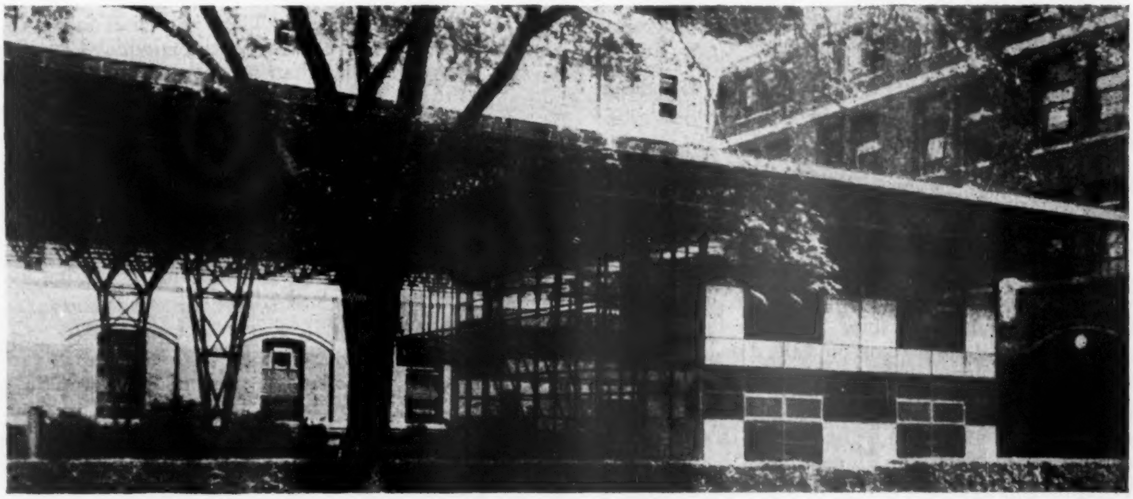


Fig. 10.

Space frame erected by students of the College of Architecture, University of Michigan, U.S.A. The building can be dismantled by wrenches and assembled elsewhere.

(Reproduced by permission of 'Architectural Design'.)

in direct connection with spare parts storage and workshops to reduce 'down' time. Small, or standardised spares such as tools or groups of tools will probably be stored near the machines and warning systems, such as toolometers, will give indication of when these particular spares will be needed.

Possible service and mechanical faults will have to be foreseen and guarded against, perhaps even to the extent of installing carry over or duplicate systems at key points and nerve centres. In which case, some warning system similar to that on the machines would give time to couple in the auxiliary supplies.

5. Flexibility will be designed into the production line and the product.

If the production line can absorb most forseeable changes, then possibly it could be given a shape which would permit economies in the building, as opposed to a building which would have to be flexible enough to allow a radical production re-routing.

If the line could be contained within a more compact shape, which would give the maximum area for the minimum perimeter walling, then the building would become cheaper. This would, of course, imply reducing the operative length of the transfer machines. But this is by no means impossible, for various automated lines in American car plants have been given return or convolution shapes ; one, at least, to fit within an existing bulding. This machine, several hundred feet long, has its effective length halved, into a 'U' shape.

Compact building shapes, such as the square and circle, containing convolution layouts, would be cheaper than a line several hundred feet long inside a narrow, rectangular building. In addition, such shapes would reduce materials handling and visual supervisory links to a minimum, simplify the running of the plant and, by further economising upon ground space, open up a new series of sites.

These brief notes are, I think, sufficient to indicate that the appearance of these buildings could be very different from their predecessors.

For example, a storage drum could be housed over the production area with raw materials fed up into it and thence gravity conveyed to the process.

Alternatively, this storage could be a physical part of a production building increased in height to accommodate it. Thus, we may eventually think of three-dimensional structures which rely for their ability to withstand loading on a third or longitudinal dimension; structures which would be a direct result of a relationship of height to plan area. We think of shapes such as a dome for a circular plan or a parabola for a long rectangular area. This may eventually lead to stressed skin structures, with cladding and structure in one, or else merely cladding spread over a frame built in sections and readily assembled and dismantled. Some of Buckminster Fuller's geodesic domes, which have achieved spans of several hundred feet, have been used as radar domes for the U.S. Armed Forces. They are built of light alloy members and are covered with plastic skin.

Perhaps further in the future are the gamma irradiated plastics, which will have tremendous strength and elasticity, and will contain all those building attributes which we now apply separately ; insulation, colour, and proof against fire. They would enable us to build soaring structures as light as bubbles.

Technically we can, of course, produce these automatic factories today. But it rather appears that they will have to await economic pressure. For the moment I think we should concentrate on arriving at this future through an adequate consideration of today's problems. One which I think we shall have to face soon is the introduction of this adequate flexibility of building, so that automation may start wherever necessary, whenever necessary, and unhandicapped by the buildings in which it is to function. This maximum flexibility can only be produced after a survey of industry's needs, in terms of automation, and building. It will, almost certainly, demand prefabrication, which is to say, standardisation, built on a module basis of construction universally acceptable to industry. With this in mind, I should like to examine the desirability of introducing a high degree of prefabrication and modular control into industrial architecture.

PREFABRICATION

Prefabrication is a technique, a rationalisation of building methods to meet changing conditions and to overcome the physical difficulties of site construction.

What do we Gain from Prefabrication ?

1. *Speed of Erection.* Time is a vital factor to industry and prefabrication, which entails assembly rather than wet construction, enables us to cut down construction time.
2. *Dry Construction.* In this country we are conditioned in our building by the vagaries of the weather. By concentrating on dry as opposed to wet construction, we free ourselves to a great extent from such dependency. Floors and roofs can go up with speed and ease and we can dispense with scaffolding by putting up walls from inside the building.
3. *Controlled Methods of Manufacture.* By manufacture off the site, rigorous control can be exercised over the production of prefabricated units to ensure uniformity and freedom from defect.
4. *Unskilled Labour.* In our designing we are governed, to a very great extent, by labour. Labour in short supply can be as strong an influence as materials in short supply. If labour is scarce and expensive, then the building must economise in man-hours. Such economy may be reflected in coarser detailing.

Moreover, years are needed to train a craftsman, whereas a machine can produce equivalent parts which will fulfil their purpose equally well and will facilitate erection by unskilled labour.

In designing industrial buildings time is important, precision is important and maintaining labour efficiency at high pitch is vital. There does then seem to be a good case for insuring ourselves against costly delays and site trouble by building as much as possible of our factories inside 'factories for factories'.

Prefabrication is, of course, extensively applied today, but in too many cases the buildings are merely copies of earlier forms in wood, concrete or metal, into which industry is bulldozed, regardless of the particular suitability of the building for the specific industry.

Systems of Prefabrication

In general, there are three main systems of prefabrication:

1. Completely prefabricated buildings ready for assembly;
2. Prefabricated units of cladding hung on to a frame;
3. Systems in which frame and cladding are one.

But whichever system of prefabrication may eventually be found to be most suitable for industry there is one vital prerequisite for a successful evolution of this method of building and that is — a wider adoption of standardisation, for it is the basis upon which prefabrication becomes possible.

Standardisation

There are two means of standardisation in common use and they are:—

Standards of performance; around which our building regulations and byelaws are designed;

and

Standards of materials and equipment; which assist the manufacturer to produce in quantity and to keep large stocks which a purchaser knows will be free from defect.

There is, however, no coordinating system to unify these standards; no universally agreed method of dimensional coordination. In house building we find that door and window manufacturers turn out countless different versions which do not vary sufficiently to be governed by aesthetic considerations. One firm in America produced a line of windows with 2,000 variations before World War II; after the War, under the guidance of modular coordination they were able to reduce the range to 300.

Experiments have been and are being carried out with the idea of instituting a suitable modular system for various types of building, whereby each building would be a repetition of a series of basic units into which ready fabricated windows, doors and equipment, panels of cladding material, etc., would fit.

Standardisation would, by permitting the prefabrication of many more building parts, provide great economies in their manufacture and distribution. But the pressing need, and one which would form the initial impetus of any standardisation, is for a standard bay.

We could discover the most economical and universally acceptable bay for industrial buildings. We could decide upon a series of standard roof loadings to condition the sizes of the members of the bay and so commence the road to standardisation.

However, although we regard standardisation as being the basis of prefabrication, knowledge is, in turn, the basis—the working tool of standardisation. We do not have this knowledge; all we know of a great number of our industries is that they are housed in outmoded buildings which soak up resources which could well be used elsewhere. Maintenance figures are astronomical and heat losses due to a lack of elementary knowledge of thermal insulation are a source of grave concern.

I am not, of course, saying that we have no superb industrial buildings, we have some of the finest in the world. But they are by no means common.

There is, then, a very great need for some basic research into industry so that we know exactly where we stand today.

The Need for Adequate Research

Surveys to produce common factors in various building types have been carried out and economies have resulted. For example, research work in schools has caused the cost of erection to drop 50% since 1949, and 82% of the school space is now used for teaching as opposed to the 35% of 1947 and 1948.

However, with industry growing in such a haphazard way, we have no way of arriving at any detailed research knowledge of our industrial buildings; nor of knowing directly which types of construction and ranges of materials have been proven suitable for particular industries, or which type of building is best in terms of design and operating costs. We cannot say offhand which methods of internal climatic control are best for individual processes; measures of control which are today essential in many processes, such as laminated glass and instrument manufacture. Consequently, architects in different parts of the country may well be busy solving the same problem in designing for a specific section of industry; a problem which may have been solved already.

Differing industries may have more in common with their building requirements than we think, thus permitting a certain standardisation, but we have no real basis upon which to commence such a standardisation economy drive for industry.

We must, therefore, carry out a large scale investigation if we are to consider rationalising our approach to industrial building. Such an investigation

would call for an early collaboration between process technologists and architects, results of which, apart from providing wide general research knowledge, could possibly initiate the use of entirely new building materials; perhaps on the built up walling system in which the constituents of the wall could be varied to suit particular requirements of individual industries.

This ignorance of any common pattern in industry is one of the major drawbacks to industrial building and one which makes its presence felt in costly, slow and complicated building techniques. In America, where the subject has been studied, factories go up in half the time taken in this country. Should this be possible here, then the increase in productivity would be worthy of the machines which turn out the goods. The building would be worthy of the process.

A programme of research into factory building and operating problems is about to be undertaken by the Building Research Station under the auspices of the Midland Regional Board for Industry. If such a survey can eventually lead to standardisation, at least in certain sections of industry, then the benefits will be manifold. This appears obvious, yet at first the project seemed likely to fail because of lack of support from industrialists and others likely to be interested. Even up to the end of last year, only half the £10,000 required had been promised.

When one thinks of the advantages of such a survey one is somewhat incredulous of the lack of interest and response. Such apathy must make us all the more purposeful if we have the interest of greater productivity at heart, to ensure that any report on industry does not gather dust and mellow in the true British tradition. As interim reports come out, they must be studied, and means of beginning any possible move to standardisation implemented, for only then will our factory buildings be made to pull their weight.

Today, I believe, we are at the crossroads leading to a new phase of industrial development and it is essential that a study of industry should take into account the full implications of automation upon our factory buildings, for any survey leading to construction on a modular basis would be affected by this new production technique.

The Attitude of the National Federation of Building Trades Employers. Building is now largely an assembly industry and builders generally are not averse to greater use of prefabrication. Although not looking upon it as the panacea for all evils, they are not opposed to the principle. Where they are experiencing a certain lack of confidence is in this question of determining a satisfactory module, or even series of modules, which would be universally acceptable and applicable to the variety of building work carried out in Britain. If architects and designers could, with the assistance of the builders, overcome this problem, then the building industry feels that it could be a most useful move forward towards higher productivity and efficiency.

Building the Factory

We require factory buildings which reduce to a minimum the number of man hours spent upon them, are simple to erect and, once up, require little maintenance. These qualities must be designed into the building so that design and the execution of that design are complementary, and not two separate and independent stages.

This requires a high degree of collaboration between architect and builder, a degree in which each is fully aware of the other's problems.

Such need for closer collaboration has long been realised and last year the Report of the Joint Committee on Architectural Education expressed the desirability for a linking of the training of the architect with that of training for management in the building industry. It was felt that when the RIBA requirements for Associateship came into force there would be an increased demand for situations on building sites, as clerks of works, etc., in order to gain practical experience. Similarly, there might be a reciprocal arrangement whereby young men from the building industry could spend a certain time in architects' offices. Architectural students would most certainly benefit by being able to observe at close hand the practical and economic aspects of design.

The building industry itself has had to surmount many difficulties in the past decade or so. A skilled labour force had to be built up after the War. There followed years of licensing and shortages of materials, some of which are still not plentiful. Invariably it has to contend with the vagaries of the weather.

Although these variables may well be beyond the control of the individual builder there are many ways in which he can improve his efficiency within his own organisation. The President of the National Federation of Building Trades Employers stated last year that although building was essentially a craft industry there was still a need for modern methods, both on the site and in the office, where experience has shown them to be both time and money saving. It was with this purpose in mind that the Federation have set up an Advisory Service for the Building Industry to take surveys for firms and advise them on how to lower their costs and increase their efficiency. They undertake investigations upon Work Study, Incentives, Materials Handling, Programming, Site Organisation, Mechanisation, Costing, Office Organisation and Personnel Administration.

Thus, it appears that we are going to see introduced into this ancient craft industry those same measures and methods of control which govern normal industrial functions.

Finally I wish to draw attention to the essential part that the client, management, can play in ensuring that we do achieve these better factories.

1. Call in the architect at a sufficiently early stage so that he is enabled to see the complete proposed development and can thus suggest

possible economies from the very earliest stages; so that the building becomes an honest answer to the particular production problem and not merely a lid over an already frozen layout.

2. Be aware of the need for long term planning so that the architect can visualise possible expansion patterns and develop the site layout accordingly.

3. Give the contractor sufficient time, after signing the contract, to plan ahead and order his materials. For three weeks thus spent at the beginning of a contract may result in an ultimate saving of time.

4. Avoid alterations during the course of the contract by adequate and early consultative planning.

CONCLUSION

My conclusion to this Paper is that we should simplify the building needs of industry. Hitherto, it has been held to be too diverse in its requirements for any classification and rationalisation. But there must be fundamentals, a knowledge of which would surely indicate that our industries had more in common with their building needs than was thought to be the case.

One thing we do know is that they have a common need for enclosed space. Consequently, if the enclosure to that space were completely flexible, so that the structure could be altered and the walls easily moved, would it not follow that such building types could possibly be used by a great many industries, thus permitting a standardisation, which would still allow individual solutions within the broad flexible concept? If we accept this, then we must concentrate upon acquiring a sound knowledge of industry's building needs, and, rather than allow such information to become an academic treatise, use it objectively for the design of buildings suitable for the greatest cross section of industry. Thus they would be enabled to play their part in production by being cheaper, simpler to erect, and more economic in operation.

Moreover, the production changes which automation may bring in factory layout would be circumscribed within a good number of 'normal' industrial buildings, whereas a completely flexible building would adapt itself easily and efficiently to meet the new circumstances. These, then, our better factories, may well be stages in the development of those fully automated factories in which we shall have as near 100% production efficiency as we are ever likely to achieve.

JOURNAL BINDERS

Strongly-made binders for the Institution Journal, each holding 12 issues, may be obtained from Head Office, 10 Chesterfield Street, London, W.1, price 10/6 each, including postage.

RESEARCH PUBLICATIONS

A number of copies of the following Research publications are still available to members, at the prices stated:

Machine Tool Research and Management	10/6
Report on Surface Finish, by Dr. G. Schlesinger	15/6
Practical Drilling Tests	21/-

These publications may be obtained from the Production Engineering Research Association, "Staveley Lodge", Melton Mowbray, Leics.

COVENTRY

ANNUAL DINNER - DANCE

Coventry are holding their Annual Dinner-Dance on Friday, 12th October, 1956, at the Masonic Hall, Coventry. The reception is to be at 7.30 p.m. for Dinner at 8 p.m. Dancing will take place until 1 a.m., liquid refreshments being available until midnight. Tickets are priced at 30/- each and can be obtained from :- W. P. Gill, c/o S. Gill & Sons (Engineers) Ltd., Lythalls Lane, Coventry.

THE PRINCIPAL OFFICERS, 1956-57

Mr. E. W. Hancock, M.B.E.

It will accord members of the Institution the greatest possible pleasure that Mr. E. W. Hancock, M.B.E., M.I.Mech.E., Hon.M.I.Prod.E., F.I.I.A., F.R.S.A., became President of the Institution on the first of this month. Mr. Hancock is one of the most distinguished production engineers in the United Kingdom. He was one of those farsighted pioneers who saw what the future held for production engineering. He became an active member of the Institution within a few months of its foundation and he has played a continuously active part in the development of the Institution. He has served on the Council for many years and he was Chairman of the Council from 1930 to 1932.

He is also a Past President of the Coventry Section and of the Wolverhampton Section. Mr. Hancock has always placed great emphasis on the training of young engineers and it was his personal advocacy which resulted in the establishment of the Schofield Travel Scholarships in 1949.

In recognition of his services to the Institution and to the profession of production engineering he was elected an Honorary Member in July, 1954.

His interests range far and wide and he has travelled to many parts of the world, including the Soviet Union, which he visited in 1928 by invitation of the Soviet Government.

He is President of the Coventry Works Sports Association and of the Coventry and District Fire Brigade Association. He is also Chairman of the Coventry Productivity Association and is a member of the Council of the Production Engineering Research Association.

His industrial career is one of great distinction and during his lifetime he has held many important positions. His great ability brought him early promotion and he was Works Manager of the Daimler Company Limited at the age of thirty-two. He is now Director and General Manager of Humber Limited, which is the manufacturing organisation of the Rootes Group.

He was awarded the M.B.E. for gallantry displayed in the Coventry air raids in 1941.

Mr. H. G. Gregory

Mr. H. G. Gregory, M.I.Prod.E., has been elected Chairman of the Council of the Institution to succeed Mr. G. Ronald Pryor. Mr. Gregory is Manager of the Northern Factories of The Fairey Aviation Company, Limited.

Mr. Gregory is Past President of the Manchester Section of the Institution. He has served on the Council of the Institution for many years and has also served on several Institution Standing Committees, and he brings to the office of Chairman of Council his very considerable experience of Institution affairs.

Mr. Gregory began his industrial life in 1917, when he was an indentured apprentice at C. A. Vandervell and Company, Limited, in London, and studied Mechanical Engineering at the Polytechnic, Regent Street. Having served his apprenticeship, he held a number of progressively senior positions, his first major appointment being Works Manager of Corfield and Buckle, Ltd., in 1930. He left this firm in 1936 to hold a senior executive position with the General Motors Corporation, and in the early years of the War was Director and General Manager of the Burtonwood Repair Depot. He joined The Fairey Aviation Company Limited in 1943.

Apart from Mr. Gregory's Institution interests, he has been a member of the Executive Committee of the Manchester District Engineering Employers' Association for some ten years, and is also Past Chairman of the Manchester and District Committee of the Foremen and Staff Mutual Benefit Society. In 1955 he was Chairman of the Consortium of Stockport Engineering Employers, which was formed in 1953, and of which Mr. Gregory is still a very active Member. He has served on the Council of the Stockport Chamber of Commerce since 1948, and was subsequently appointed Chairman of the Membership Committee. He is also on a Machine Tool Project Advisory Panel, formed in December of last year by The National Research Development Corporation.

Among Mr. Gregory's hobbies are dinghy sailing, golf and horticulture.

Production Engineering Research Association of Great Britain

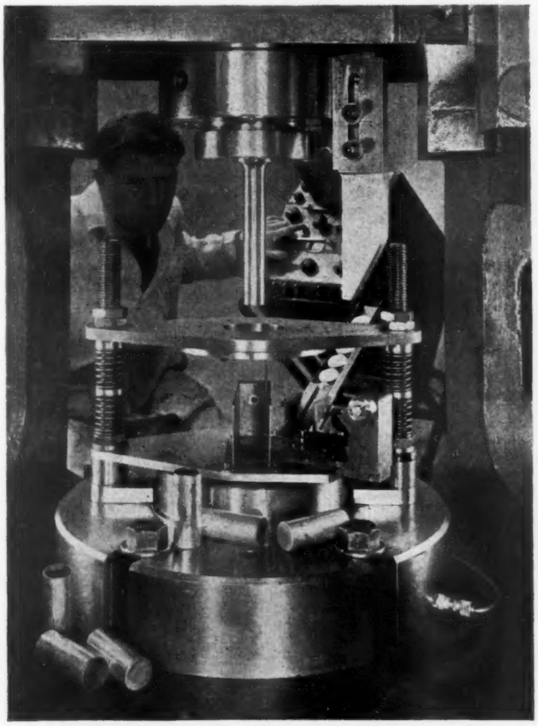
PERA

Quarterly Newsletter to the Institution

APRIL, 1956

Monthly Bulletin

Details of PERA's training schemes for managers, superintendents, foremen, etc., were given in the January issue of the bulletin. These courses, which are attended by many hundred personnel from member firms, provide up-to-date information on production techniques, and advice on the application of PERA's research results by means of demonstrations, lectures, films, and discussions. Special instructional courses on productive subjects such as tool grinding and machine tool maintenance are provided to meet the requirements of individual firms. The February issue of the bulletin contained a summary of the results of PERA's research on the quality of taps. It was found that very great differences occured in the performance of taps made by different manufacturers, tap-life varying between 30 and 3,000 holes tapped between regrinds, when compared under closely controlled cutting conditions. Reference was also made to the assessment of surface finish using plastic replicas. PERA has recently issued a report indicating the accuracy of assessment which can be achieved when comparing replicas on the basis of the images transmitted to a screen by beams of light passed through the replicas and subsequently focussed on to the screen. In March the bulletin gave a brief report on the progress made in cold impact extrusion of steel including comments on the effect of variations in slug thickness and the thickness of the walls and base of extruded components.



Impact Extrusion Research in Progress at PERA

Film Production

A new PERA film was completed in March, on the subject of blanking and piercing. It refers to features of punch and die design which contribute to maximum tool life and highest quality and accuracy of the parts produced. This is the fifth film made at PERA, previous films having been devoted to tool grinding, impact extrusion, automation, and the operation of PERA research and information services. Further films are at present being made on drilling operations and the use of cutting fluids.

Research Programme

A survey of automation techniques was begun in January when the first nominees from industry to participate in this work arrived at PERA headquarters to join the research team working on the first stage of the programme. As a preliminary to making a series of industrial visits to study the merits of various mechanized operations on both machining and presswork, an extensive survey of published information and special reports is being made. About 2,500 British and foreign sources of reference have been examined for useful data on equipment for reducing handling times between operations, and equipment with special localized applications to

(*Continued on page* 472)

MATERIALS H

CASE STUDY No. 4

Crankshafts—Receiving, Storage and Internal Transport

Firm: **Vauxhall Motors Limited.**

The Company. *A total of* 15,000 *are employed at this Company in the various production processes or control functions of motor car production.*

The Source. *Prior to* 1949, *Materials Handling Planning had been a function of the Factory Layout Department but due to rapid expansion of the factory and the obvious need for extensive study of the latest handling methods and their application to present day needs, a separate section was formed.*

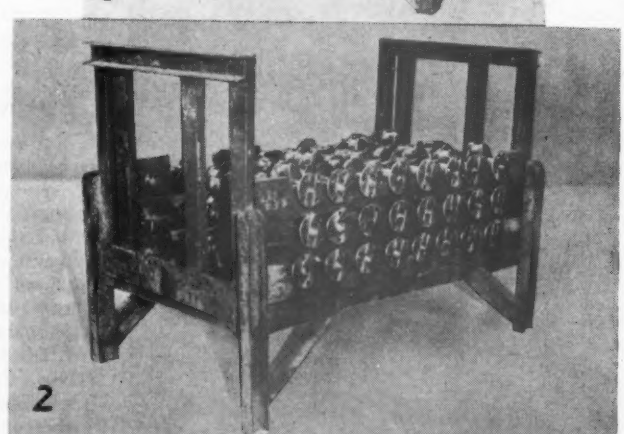
The Materials Handling Planning Section deals with materials handling problems both current and future. The permanent staff of this section consists of twelve engineers, and this is supplemented by four to six apprentices each spending four months in the section as part of their general training. During this time the apprentices cover draughting and assist in engineering study.

Approach. *Each Material Planning Engineer is responsible for materials handling in a certain area or under a certain function of the factory, and it is his duty not only to plan materials handling methods, but constantly to study means of improving existing methods.*

Each engineer therefore is frequently engaged in detailed material handling studies.

old method

1



2

HANDLING

new method

OLD METHOD

The crankshafts were previously delivered to the factory in cases of the design shown in illustration (1), but of various sizes. On account of their lack of uniformity they could not be stacked without the use of dunnage of various thicknesses. Nor could these cases be used on the engine assembly line because the crankshafts were so closely packed that a sling could not be used for lifting them out.

The procedure, therefore, was to unpack the cases in the stores and stand the crankshafts vertically on their flanges on a wooden raft.

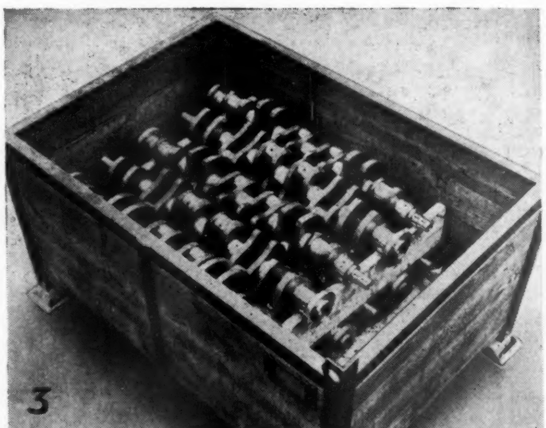
When needed on the engine assembly line the crankshafts were transported in a special portable rack as shown in illustration (2).

The disadvantages of this method were :-

(a) Difficult stacking of cases;

(b) Excessive handling of crankshafts, i.e. from cases to storage;

(c) Wasteful use of floor space for storage raft.



3

4

NEW METHOD

These disadvantages were overcome in the following manner. A suitable number of standard factory stillages were fitted internally with wooden bearers which permitted the crankshafts to be lifted out by slings, see illustration (3). Hinged lids were also fitted. By arrangement with the crankshaft manufacturers these stillages are used for the transport of crankshafts between the two works. On arrival at the user's end, the stillages are stacked in the stores pending issue to the engine assembly line, when the stillages and their contents are issued as a unit load, illustration (4).

Advantages. The savings obtained by the introduction of the new method were :—

(a) 60 man hours per week;

(b) 600 square feet of floor space.

COUNCIL ELECTIONS 1956-57

As a result of the Ballot the following Members have been elected to serve for the year 1956 - 57 :-

Members :

H. W. Bowen, O.B.E.	A. Griffiths, O.B.E.	A. L. Stuchbery
H. Burke	S. J. Harley	C. Timms
F. J. Everest	H. W. Hodson	

Associate Member :

L. S. Pitteway

The next Council Meeting will be held at 10 Chesterfield Street, London, W.1, on Thursday, 19th July, 1956, at 11 a.m.

PERA QUARTERLY NEWSLETTER—

continued from page 469

particular machining and presswork operations. It is expected that at least nine engineers from member firms will participate in the work of this research team.

The practical work is now completed for the investigation into the effects of point angle and relief angle on drill performance when drilling low and medium carbon steels. Similar work on drilling of alloy steel is in progress. An investigation into the effects of steel analysis and metallurgical condition on the machining properties of medium carbon steels has also been completed.

Tests are in progress to compare the efficiency of a variety of lubricants used for deep drawing brass. The effect of blankholder pressure on the maximum depth of component obtainable is also being studied.

An investigation has been commenced to determine the relative rates of wear of various tool materials when blanking and piercing mild steel, stainless steel, and electrical lamination steel. This work is being carried out on a double roll-feed press capable of operating at 600 strokes per minute.

Further researches are now being carried out on the metallurgical requirements of steels for the impact extrusion process, and the use of phosphate coatings for lubrication. It is hoped that steel components larger than those extruded up to now will be successfully produced using the special 1,000-ton press installed at PERA. The data arising from the production of these larger components at PERA will, it is believed, encourage industry to aim at greater exploitation of this highly efficient process.

NEWS OF MEMBERS.

Mr. G. L. Brough, Member, has taken up an appointment as Superintendent Engineer with Gray, Mackenzie & Co. Ltd., Engineering Department, Bahrein, Persion Gulf.

Mr. G. Smithies, Member, has relinquished his position as Works Engineer with Turner Brothers Asbestos Co. Ltd., and has taken up a new appointment as Executive Engineer with Thomas Bradford & Co. Ltd., Salford.

Mr. R. Clarkson, Associate Member, has been appointed a Director of C. Jackson & Son, Warwick, in addition to his duties as General Manager.

Mr. S. Critchley, Associate Member, has now returned to the Luton and Sundon Works of the Skefko Ball Bearing Co. Ltd., Luton, as Plant and Research Engineer.

Mr. G. C. Fairbanks, Associate Member, Group General Manager of Elliott Brothers (London) Limited, has been appointed to the Board of the Bristol Instrument Co.

Mr. A. A. Jacobsen, Associate Member, has been appointed Works Manager of the Witney Works of The Motor Accessories Division of S. Smith & Sons Limited. He was previously Works Manager of Normalair Limited, Yeovil.

Mr. N. Herbert, Associate Member, has taken up an appointment on the staff of the College of Technology, Chesterfield, as Lecturer in Production Engineering.

Mr. D. F. H. Rushton, Associate Member, has now been appointed Works Manager of C.I.C. Engineering Limited, a newly formed subsidiary of C. and J. Clark Limited.

Mr. G. H. Spearing, Associate Member, Works Manager of Newton & Bennett Ltd., has been elected to the Board of the three Companies, comprising the Group, namely, Newton & Bennett Limited ; Power Jacks Limited ; and Newton Motor Products, Acton.

Mr. G. Walkinshaw, Associate Member, has joined the Management of Bucyrus-Erie Ltd., South Milwaukee, U.S.A.

Mr. J. H. Beddard, Graduate, has relinquished his appointment as Jig and Tool Designer-Draughtsman with Messrs. Crompton Parkinson Ltd., Doncaster, and has taken up a position as Technical Teacher at the Doncaster Technical College.

Mr. N. J. Bullock, Graduate, has recently been made Section Leader in the Planning Dept. of D. Napier & Sons Limited, at their Raynes Park Works.

Mr. R. A. Foley, Graduate, has relinquished his position of Chief Designer with M. O. Valve Co. Ltd., and has taken up an appointment as Manager of the Valve Department of Messrs, Alan Muntz & Co. Ltd.

Mr. P. W. Millyard, Graduate, is now employed as a Planning Engineer by The English Electric Co. Ltd., Stevenage.

Mr. R. Morris, Graduate, has relinquished his position of Chief Planning Engineer with Light Alloys Limited, and has now joined Harold Whitehead & Partners as a Production Consultant.

Mr. W. A. J. Wilson, Graduate, has relinquished his appointment as Toolmaker with F.N.F. Limited, Burton-on-Trent, and has now taken up a position as Method Engineer with Rotax Limited, Hemel Hempstead.

OFFICIAL OPENING OF THE
PRODUCTION EXHIBITION AND CONFERENCE — **concluded from page 415**

well to draw upon. Large firms and small firms have pooled their ideas in this Exhibition. They are showing us the way ahead to progress and to productivity, and this is the key problem in our economy at the present time. If we solve this, the problems which seem so formidable now, will fall into place. I believe this Exhibition plays a truly important part in showing us the way forward, and I have much pleasure in declaring the second Production Exhibition and Conference now open."

Mrs. M. A. Montgomery, Managing Director, Andry Montgomery Limited, expressed appreciation to the Minister on behalf of the Exhibition organisers and of the Institution of Production Engineers. She also thanked all those who contributed in various ways to make the Exhibition possible, and in closing her remarks said : " I should like also to thank all those people who have helped so much in many little ways, particularly the West Ham Technical College, who, with no money at all but with great good will on everybody's part, have put on a remarkable exhibit. It has been done purely by students and others who have helped by the kindness of their hearts, and the indefatigable Dr. Stein. Anything we have been able to do to put salt on the tail of this rather elusive bird, productivity, we have been very glad to do so, and we are particularly grateful to the Minister for coming here and opening this Exhibition."

INSTITUTION NOTES

MIDLANDS REGION ANNUAL CONFERENCE

The Annual Conference of the Midlands Region of the Institution, which was held at the works of the Austin Motor Company on Wednesday, 16th May last, was an outstanding event in the history of the Region, and was attended by nearly 600 members and guests, the application list having to be closed more than a week beforehand.

The Conference assembled at Longbridge at 9 a.m., when the principal members of the party were received by Sir Leonard Lord, K.B.E., Chairman of the Corporation and President of the Institution. An address of welcome was given by Mr. H. J. Graves, Director of the Austin Motor Company, Ltd.

The morning was spent touring the factory, special attention being paid to transfer in line and rotary unit head machines, and automatic assembly, including the car assembly building.

After luncheon, the Conference assembled in the new Exhibition Hall which had just been completed, to hear three short Papers, as follows :-

" An Outline of the British Motor Corporation's Developments in the Field of Automation ", by Mr. H. J. Graves.

" Design and Manufacturing Problems " by Mr. H. W. Holbeche, Chief Production Equipment Engineer, British Motor Corporation.

" An Outline of Processes and Assemblies and Material Movement " by Mr. F. Griffiths, Production Development Engineer, British Motor Corporation.

The Conference organisers had selected these subjects to complement the works visit in the morning, and this arrangement was most successful. The opening speaker, Mr. Graves, gave a broad picture of the Corporation's developments in mechanisation of production since the end of the Second World War, and Mr. Holbeche and Mr. Griffiths described in more detail the problems encountered and progress made in the detail planning and design and manufacture of transfer and unit machines and other automatic equipment.

The three Papers provoked a very spirited discussion, which was opened by Mr. F. B. White, Director and General Manager of Guest, Keen & Nettlefolds, Ltd., and Mr. Bernard Jackman, General Manager of the Automotive Division, Lockheed Hydraulic Brake Company, Ltd., Leamington, and was wound up by Mr. F. G. Woollard, M.B.E. Interest was so keen that there was difficulty in closing the meeting, which overran the scheduled time.

This Conference comprised the largest party ever received at Longbridge, and great appreciation was expressed for the splendid arrangements and outstanding hospitality provided by the Austin Motor Company.

HONOURS

The Institution records with pleasure the following awards made to members in Her Majesty the Queen's Birthday Honours' List :-

Knight Bachelor

Mr. G. H. Dowty, Member, Chairman of Dowty Group Limited, Cheltenham, Glos.

C.B.E.

Mr. R. M. Currie, Member, Head of Work Study Department, Imperial Chemical Industries Limited. Mr. Currie is a member of the Conference Advisory Committee.

M.B.E.

Mr. A. H. Selby, Associate Member, Production Manager, George W. King Ltd., Stevenage, Herts.

LECTURES ON " AUTOMATION AND CYBERNETICS " AT BRISTOL UNIVERSITY

A series of lectures on six Friday evenings has been concluded recently by Dr. F. H. George and Mr. D. J. Stewart of Bristol University Department of Psychology. The audience numbered between two and three hundred, and was by no means confined to engineers. It followed a short course on computers, and is likely to be succeeded by a longer course on automation with an engineer added to the lecturers.

The approach was necessarily general, and surveyed a number of related fields of scientific endeavour. Cybernatics was considered as the theoretical basis of Automation. It draws from the general theory of control and communication, and its prime concept is information.

Although both automatic computation and feedback are likely to appear in any development of automation, the lecturers held the view, which will interest production engineers, that " automatic " and " automated " are not precise separations, but a continuum. The automatic lathe is covered by the general theory as well as machines which can "think" and " choose ", and machines which are self-maintaining or even self-reproducing. To the delight of the audience it was demonstrated that such machines are theoretically possible, small as may be the chance of putting them to work economically in the near future.

A list of thirty selected books was supplied for further reference. One is the I.Prod.E. report of the conference on " The Automatic Factory—What Does It Mean?" Another, of special interest to us, is " The Living Brain ", which describes research with the aid of the electroencephalograph, and the conception and construction of simple machines which stimulate the human operations of reflex behaviour, recognition and learning. The author is Dr. Grey Walter, of the Burden Neurological Institute, Bristol. He is to deliver the Institution's 1956 Nuffield Lecture at the University here on Wednesday, October 17th, and this event is anticipated with great interest.

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REVIEWS AND ADDITIONS

"Dimensions and Tolerances for Mass Production" by Earle Buckingham. *New York, Machinery Publishing Company Limited,* 1954. 164 *pages. Diagrams.* 75s. 0d.

The book under review covers far more ground than the reader would be led to expect from the title. The author considers all the aspects of dimensioning as they are generally understood today. If this information is all that the reader seeks, he would be better advised to study the early publication, "Dimensional Analysis of Engineering Designs" (H.M.S.O. 1948), or its more polished successor, "The Dimensioning of Engineering Drawings" by Dr. Abbott (Blackie, 1953).

Professor Buckingham devotes a considerable portion of his book to the subject of designing for production and improved function, and incorporates with this a series of gauge designs for the parts under consideration. Certain of the gauge designs are only diagrammatic, but in most cases the principles of design are sound.

In many cases the author has prepared fully-dimensioned working drawings of components suitable for use in factories which are mass producing.

This book is easy to read and the information is practicable, with the exception of one or two rather optimistic designs.

The book is aimed principally at designers and draughtsmen and, used with discretion, it should be of interest and value to them. Teachers of jig and tool design may find some useful examples in this book. Advanced students of production engineering could also profit from its pages.

S.R.S.

"Fundamentals of Press Tool Design" by W. F. Walker. *London, Crosby Lockwood,* 1955. 152 *pages. Diagrams.* 12s. 6d.

As its title implies, the book is intended to convey the fundamental principles employed in the design of Press Tools.

Cupping and Drawing, for example, has been the subject of considerable research, and in consequence several eminent men have had complete volumes published, but Mr. Walker has contrived to pack into 15 or 16 pages the essential requirements of such tools.

The subject of cutting action and the effect of clearance is also treated in a similar manner.

Considerable variations exist in the terminology used to describe various press tool operations, but in order to eliminate any possibility of misconception, the author has defined each operation before describing them. Roughly twenty typical press operations are described with the aid of some well-chosen examples, whilst the final chapter provides a guide to the selection of tool steels and their heat treatment.

The text, which is concise and easily followed, is made more explicit by the use of many well executed drawings.

Several tables and formulae complete the book and make it a useful reference work to the student in particular.

A.J.V.

"The Challenge of Automation": Papers delivered at the National Conference on Automation, Washington, 1955. *Washington, Public Affairs Press,* 1955. 77 *pages.* (The Conference was held under the auspices of the Committee on Economic Policy of the Congress of Industrial Organisations.)

Chief Inspector of Factories. **"Annual Report for the year 1954."** *H.M.S.O.,* 1955. 265 *pages. Illustrated. Diagrams.* (Cmd. 9605.)

Connell, Robert S. **"Tool and Cutter Grinding."** *Brighton, Machinery Publishing Co.,* 1955. 159 *pages. Illustrated. Diagrams.* (Machinery's Standard Reference Series.)

Drucker, Peter F. **"The Practice of Management."** *Heinemann,* 1955. 355 *pages.*

Flood, W. E. and West, Michael (editors). **"Explaining and Pronouncing Dictionary of Scientific and Technical Words."** 2nd edition. *Longmans Green,* 1953. 397 *pages. Illustrated.*

Ford (Henry) Trade School, Dearborn, Michigan. **"Shop Theory."** 4th edition revised. *New York, McGraw-Hill,* 1955. 329 *pages. Illustrated. Diagrams.*

Holzbock, Werner G. **"Instruments for Measurement and Control."** *New York, Reinhold; London, Chapman & Hall,* 1955. 371 *pages. Illustrated. Diagrams.*

Institution of Civil Engineers, London. **"List of Members 1955."** *London, the Institution,* 1955. 685 *pages.*

Institution of Structural Engineers, London. **"Year Book and List of Members 1955."** *London, the Institution,* 1955. 327 *pages.*

Institute of Petroleum, London. **"Symposium on Metal-working Oils. Part 1: Metal Cutting; Part 2: Metal-forming"**: Report of a meeting held by the Institute of Petroleum, 19th March, 1954. Reproduced from The Journal of the Institute of Petroleum, September and October, 1954.

Ireson, W. Grant and Grant, Eugene L. (editors). **"Handbook of Industrial Engineering and Management."** *Englewood Cliffs, N.J.,* 1955. 1,203 *pages. Illustrated. Diagrams.*

Technical Papers and Panel Discussions Presented at the 23rd Annual Meeting. American Society of Tool Engineers, Detroit, Michigan. *Detroit, The Society,* 1955. 40 *parts in binder. Illustrated. Diagrams.* $5

This collection comprises sixteen Papers, the reports of four panel conferences, and the first A.S.T.E. Research Report. The latter, by Dr. Victor Paschkis of the Heat and Mass Flow Laboratory of Columbia University, reports the results of investigations into the use of electric analogue computers to determine the temperatures encountered during metal cutting. The Papers cover a wide range of subjects including the Coding of Enginering Drawings; Magnesium Tooling; Research on Twist Drills and Drilling; Investment Casting by the Frozen Mercury Process; and Tooling for Cold Steel Extrusion.

The four panel conferences consist of four of five Papers besides the discusssion. The subjects discussed are:-Plastic Tooling for Production; Preparing Engineers for Manufacturing Responsibilities; Co-ordination of Manufacturing Management; and Quality Control through Realistic Tolerances. The panel conference on Preparing Engineers for Manufacturing Responsibilities includes Papers on "in plant" training in both large and small organisations, and one on The Specialised Curriculum in Manufacturing Engineering, in which Mr. R. J. Smith attempts a "functional classification in manufacturing engineering". He clearly distinguishes (at least for the purposes of his Paper) between the Production Engineer, the Industrial Engineer and the Tool Engineer.

The standard of illustrations throughout the volume is high, and valuable bibliographies are appended to many of the sections.

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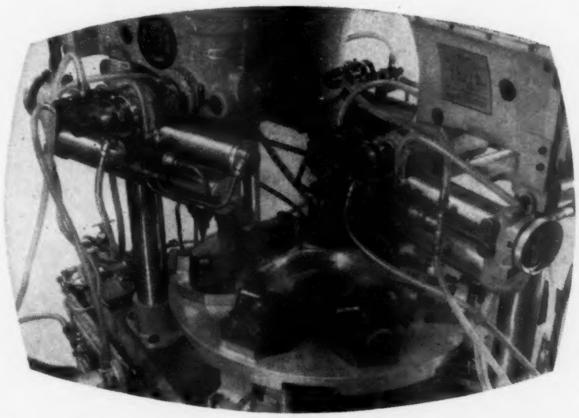

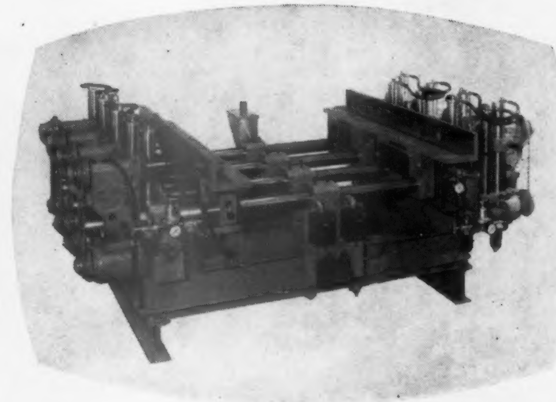

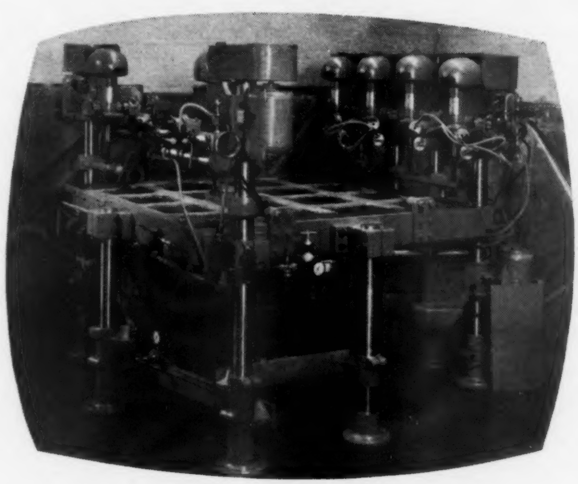

- ***Above right:*** A machine for drilling 16 holes in a 54 in. x 52 in. component. 8 heads at 12 in. centres operate simultaneously. Component is automatically moved to next station and the operation repeated, leaving 16 holes at 6 in. centres. Floor to floor time 47 seconds; previously, the operation required 15 mins. 10 secs.
- ***Above left;*** Progressive drilling followed by tapping on a special Hammer Head. Three operations performed simultaneously and in sequence with automatic table indexing. Floor to floor time 33 seconds; previously, the operation required 2 mins. 15 secs.
- ***Below left:*** A machine for drilling 18 holes in a 54 in. x 52 in. component. Firstly 8 heads directly opposed at 6 in. centres operate simultaneously. The component is rotated through 90 deg. when 10 heads again operate to complete. Floor to floor time 47 seconds; previously, the operation required 15 mins. 10 secs.

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RADIAL DRILLING MACHINE

This is a 7ft. radius machine operating on large bed castings

INTERNATIONAL MACHINE TOOL EXHIBITION 1956
June 22–July 6
Olympia · London

NATIONAL HALL, STAND No. 117

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The Asquith O.D.4 is a Particularly robust radial drilling machine with adequate rigidity for the maintenance of accuracy in holemaking in the Heavy Machine Shop. It is available with radius up to 12ft. The maximum drilling capacity in steel is 4 in.

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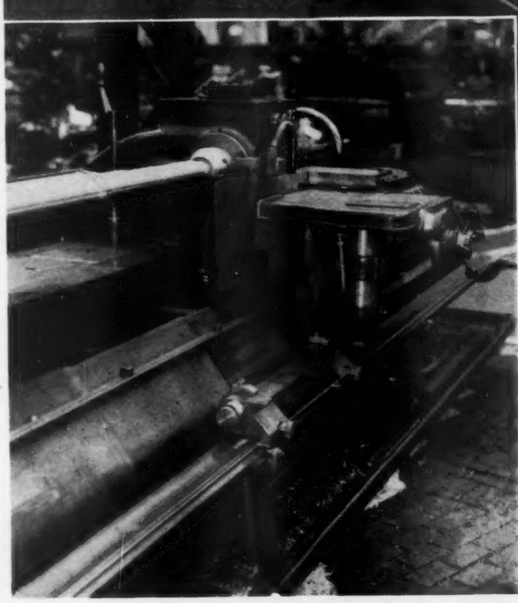
MAXICUT

ELECTRONIC COPY TURNING

simplifies and speeds up production of large multi-diameter shafts



Two 'Maxicut' Machines (8' 6" between centres) are employed by RUSTON-BUCYRUS LTD. for machining large excavator shafts. The example shown is a forward shaft for a 22RB type Excavator. The lower illustration clearly shows the tracer head of the machine, and the template being used can be seen mounted on the carrier at the bottom right of the illustration.

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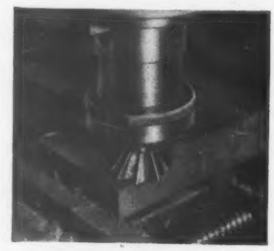
the finest cutting teeth in the business!

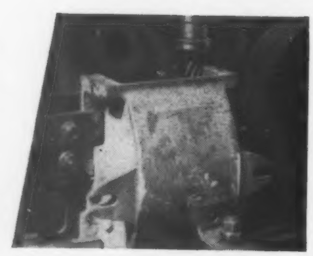
THE FEEDS AND SPEEDS GIVEN HERE ARE OBTAINABLE ON NORMAL PRODUCTION RUNS . . . .

AUTOLOCK $1\frac{3}{4}$ END MILL facing nickel chrome cast iron. 114 r.p.m. with roughing and finishing cut to obtain very good accurate finish.

STANDARD AUTOLOCK DOVETAIL cutter $1\frac{1}{4}''$ dia. 60° angle rough milling cast iron slide 150 r.p.m. 3″ per minute feed. These cutters are stocked in all our branches $\frac{1}{2}''$ to $1\frac{1}{4}''$ dia. with 60° and 45° angles.



AUTOLOCK $1\frac{3}{16}''$ END MILL cutting recess in housing cover. Material cast iron 205 r.p.m. $1\frac{1}{2}''$ per minute $\frac{1}{4}''$ deep. Clarkson End Mills are designed as versatile tools giving high performance over a wide range of materials.



more examples in future issues!

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British Oxygen Gases Limited, Industrial Division, Bridgewater House, St. James's, London, S.W.1

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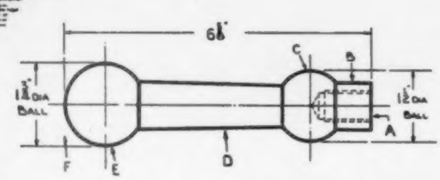


Floor to Floor Time: 4 minutes **CLUTCH LEVER**

Fitted with 2" Hand Operated Automatic Chuck and 2" Capacity Bar Feed

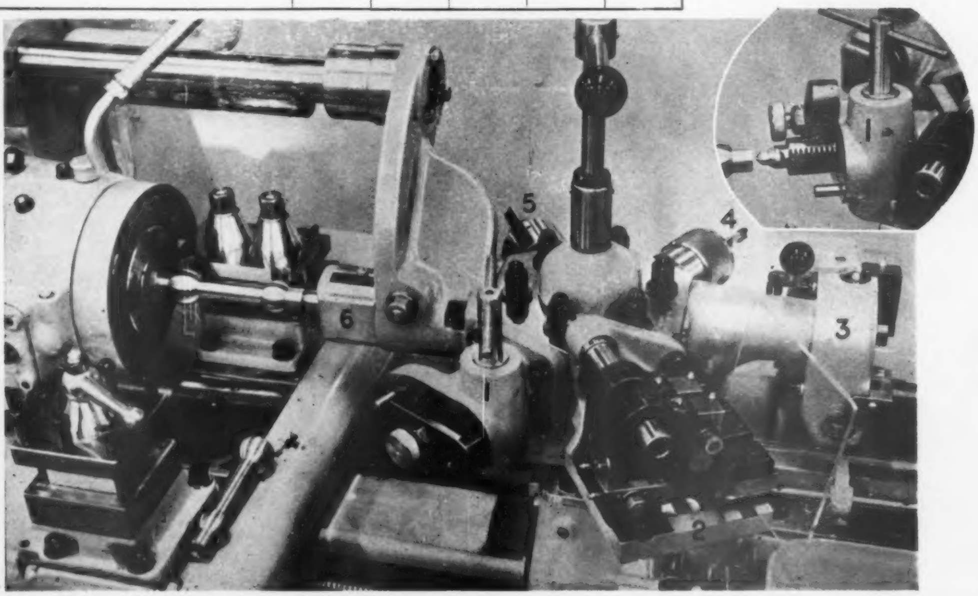
1⅝" dia. Free Cutting Mild Steel, En.1.

Tungsten Carbide and High Speed Steel Cutting Tools

Ward

No. 7 CAPSTAN LATHE

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
Feed to Stop, Chuck, Start Drill A	1	—	1000	130	Hand
Multiple Roller Turn B and C dias. and Face End	2	—	1000	460	133
Parallel Undercut turn D	3	—	1000	460	193
Drill A	4	—	1000	130	Hand
Tap ⅝" dia. × 14 T.P.I.	5	—	177	30	14 T.P.I.
Support and Form C, D, E	6	Rear	177	80	Hand
Radius Part-off F	--	S.T.1	146	30	Hand



Capacity: 2⅛ in. dia. hole through spindle 16¼ in. dia. swing over stainless steel bed covers.

Spindle: Mounted in ball and roller bearings

Powerful metal-to-metal cone clutches transmit power through ground gears.

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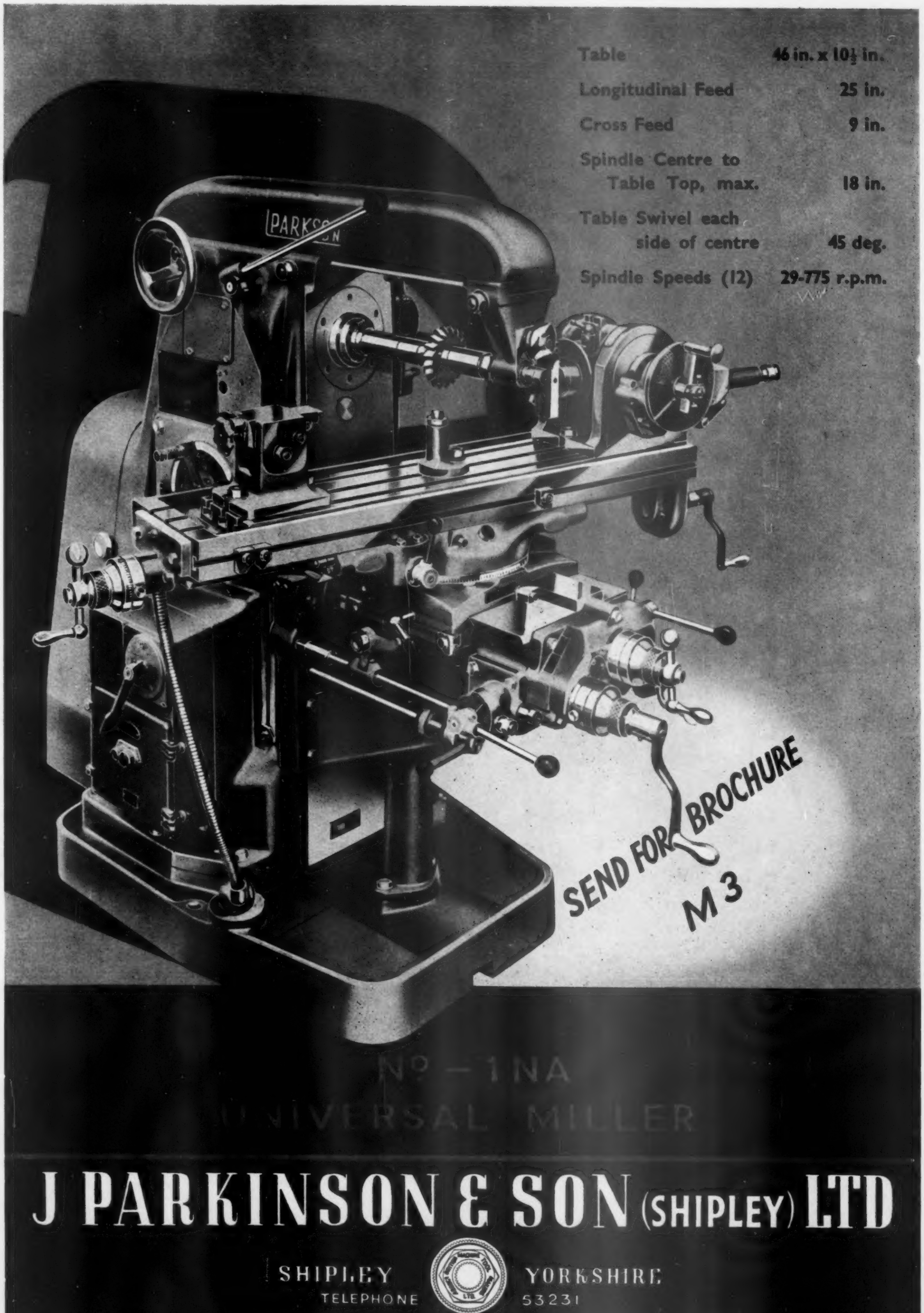
Table 46 in. x 10½ in.
Longitudinal Feed 25 in.
Cross Feed 9 in.
Spindle Centre to Table Top, max. 18 in.
Table Swivel each side of centre 45 deg.
Spindle Speeds (12) 29-775 r.p.m.
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SEND FOR BROCHURE
M 3
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UNIVERSAL MILLER
J PARKINSON & SON (SHIPLEY) LTD
SHIPLEY YORKSHIRE
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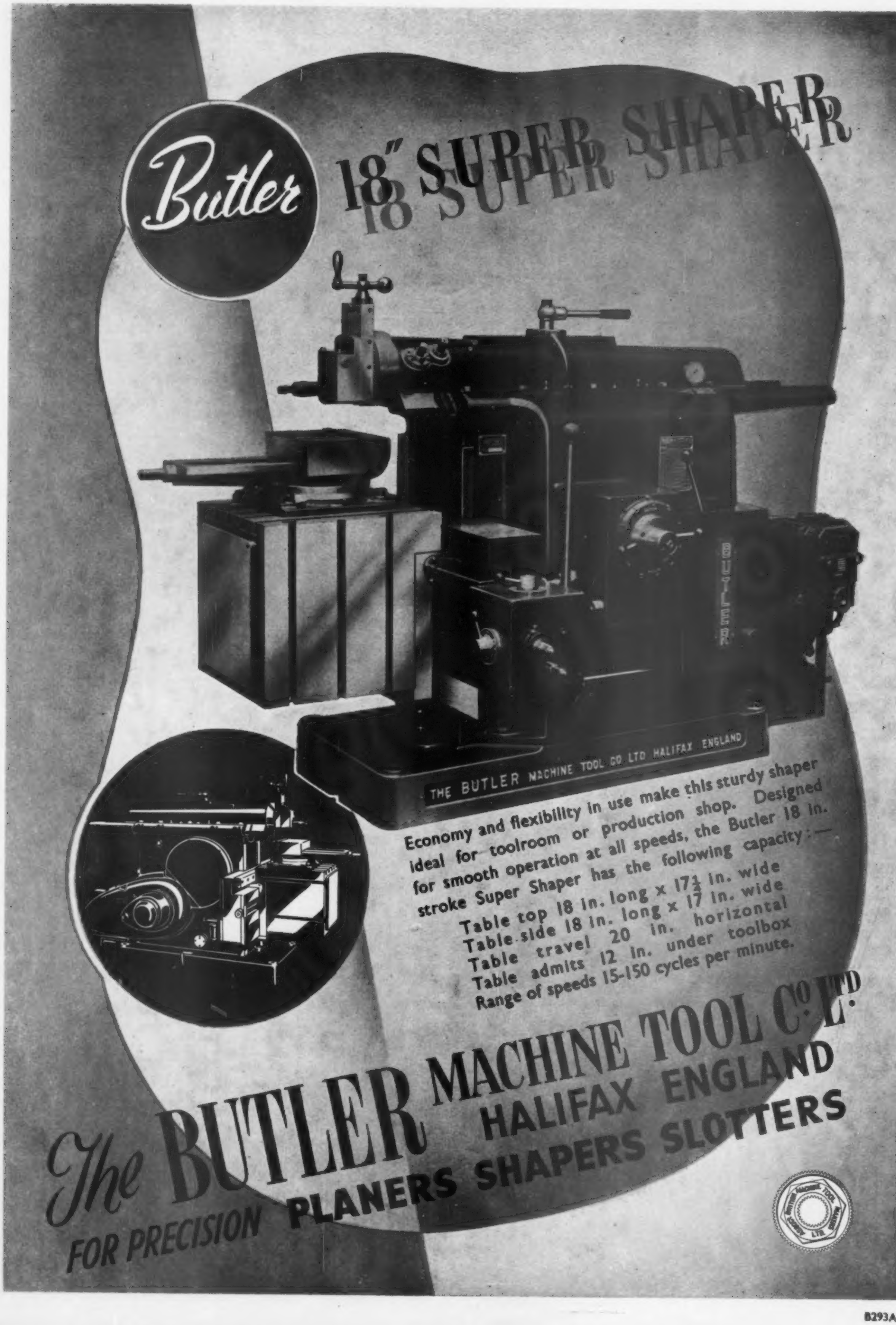
P367 C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THE BUTLER MACHINE TOOL CO LTD HALIFAX ENGLAND
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Table admits 12 in. under toolbox
Range of speeds 15-150 cycles per minute.
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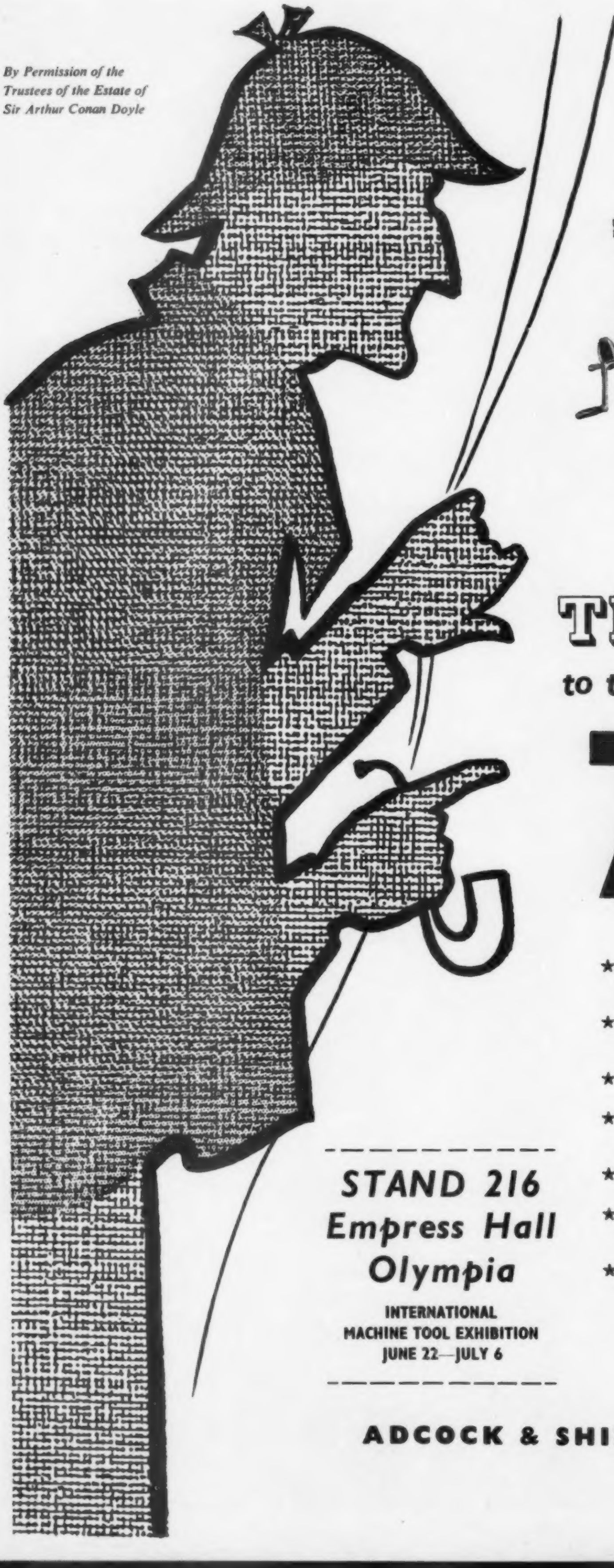
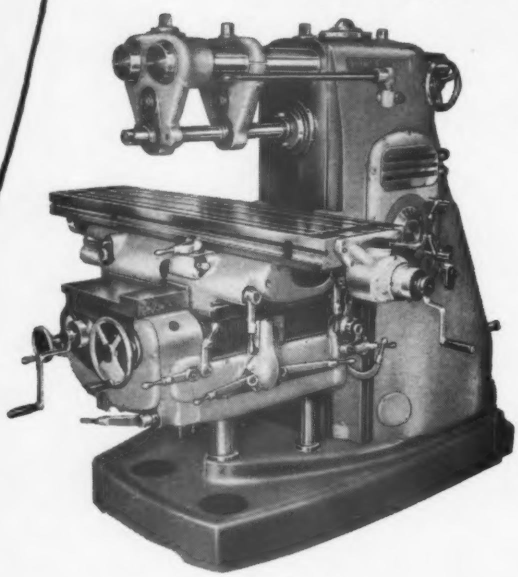


The NEW 3HG Milling Machine



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to the A. & S. Mystery

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- ★ **4HG HORIZONTAL MILLER**—a new version of the 4AG—heavier—wider knee—automatic lubrication of all slides and screws.
- ★ **NEW No. 2 UNIVERSAL MILLER**—with rapid traverse in all directions.
- ★ **2VSB SWIVEL HEAD VERTICAL MACHINE**—a heavier and more powerful version of this well known machine.
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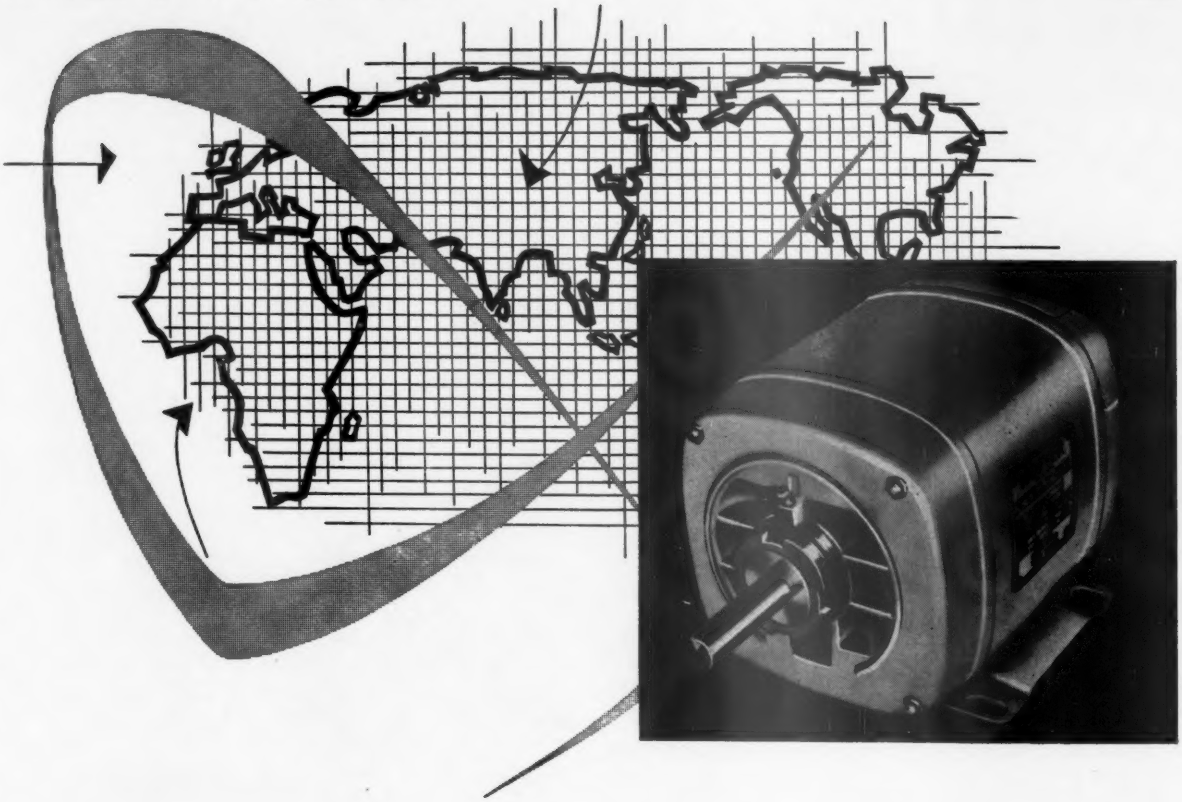

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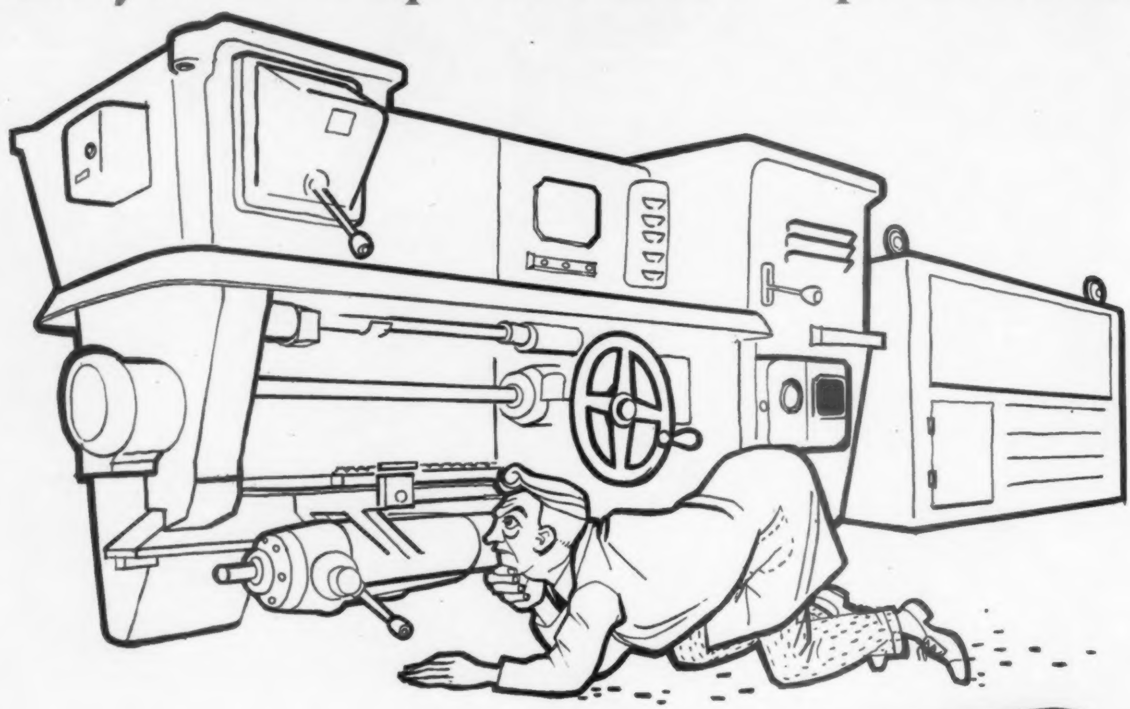

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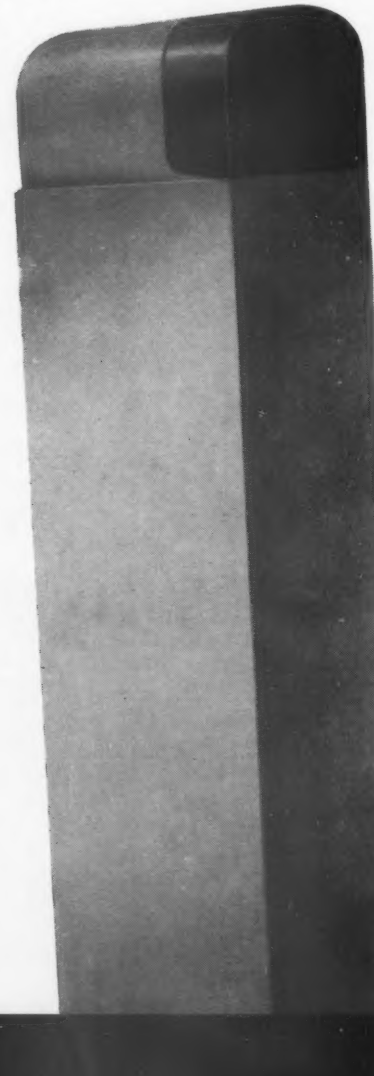

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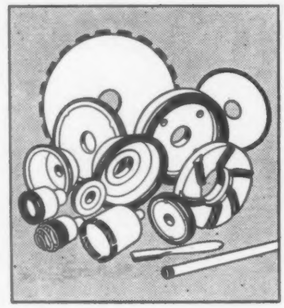

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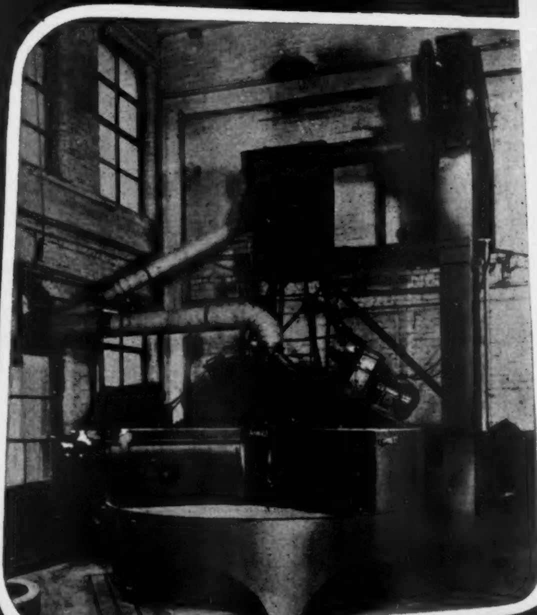

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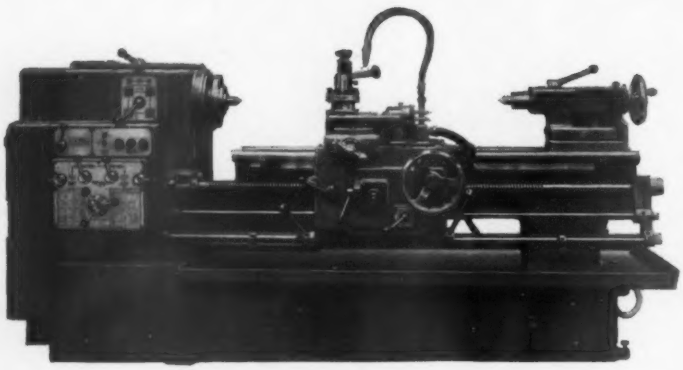

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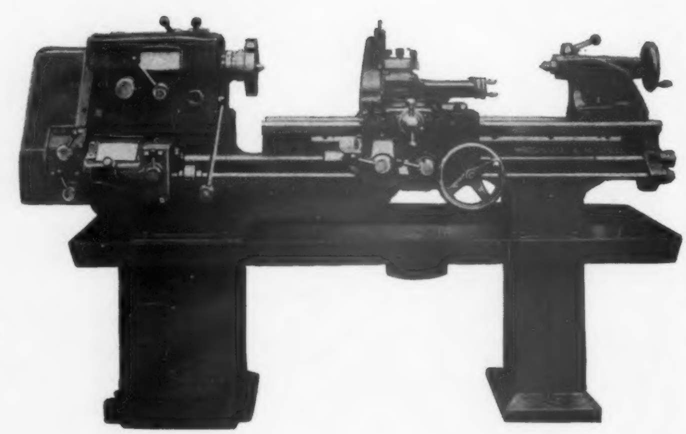

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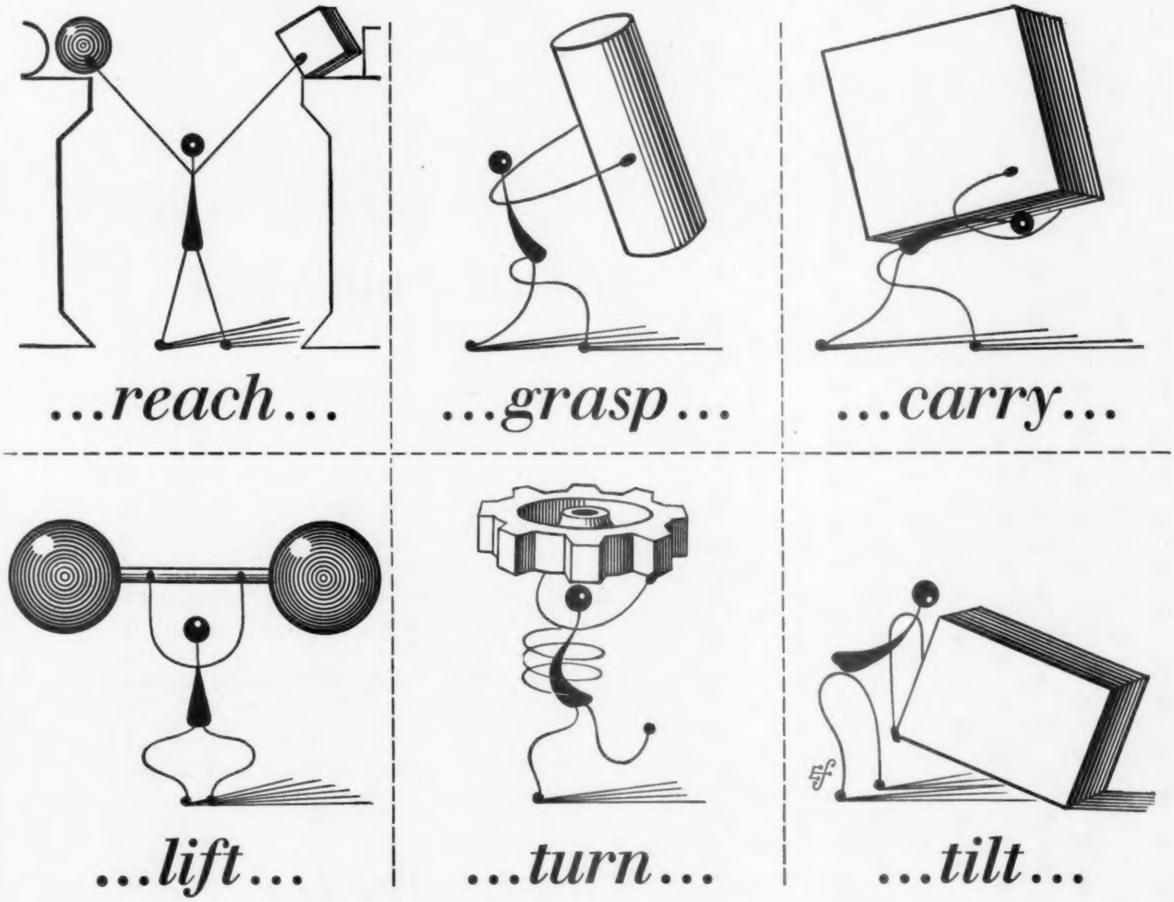

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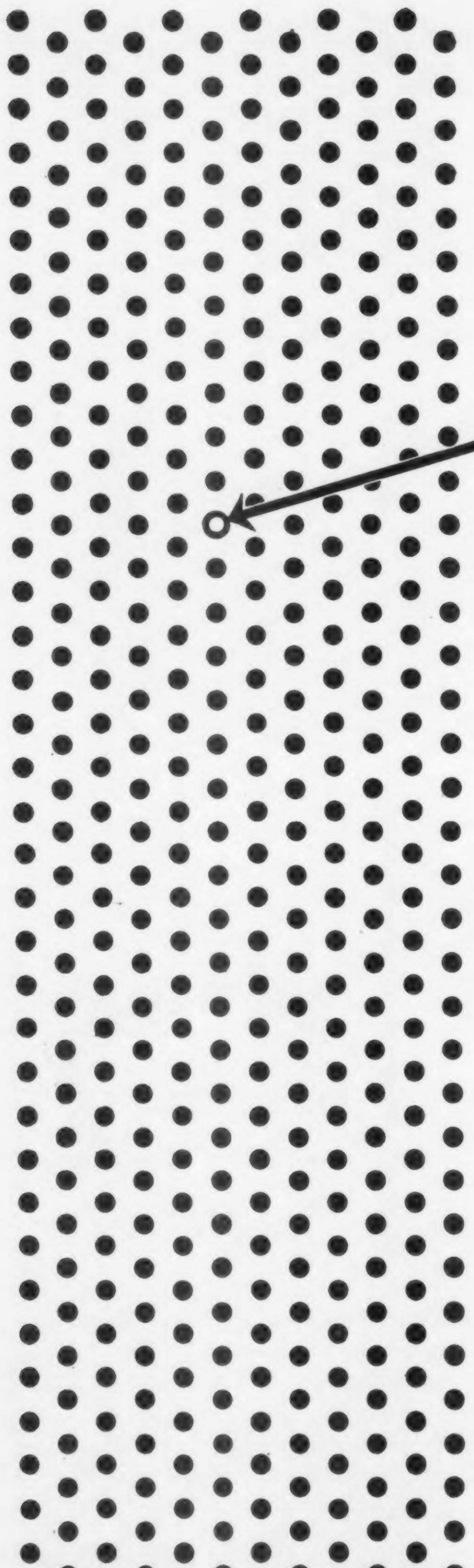

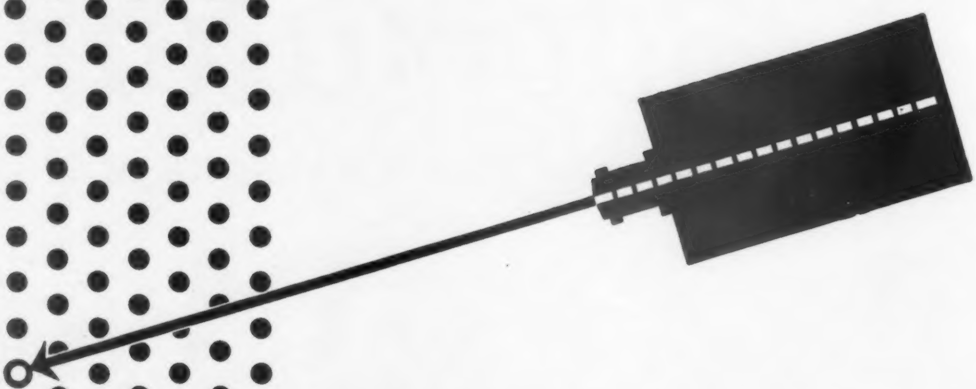

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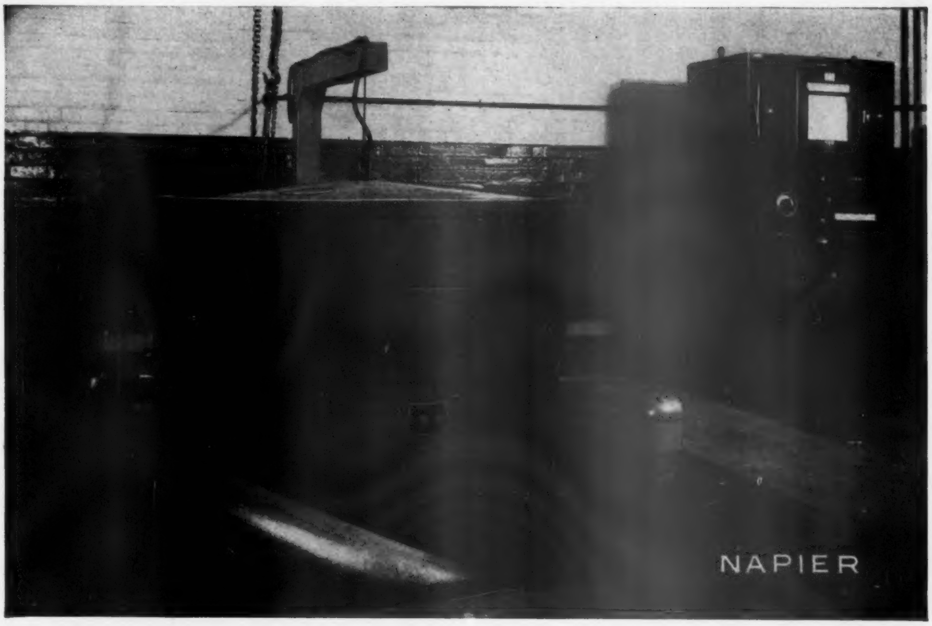

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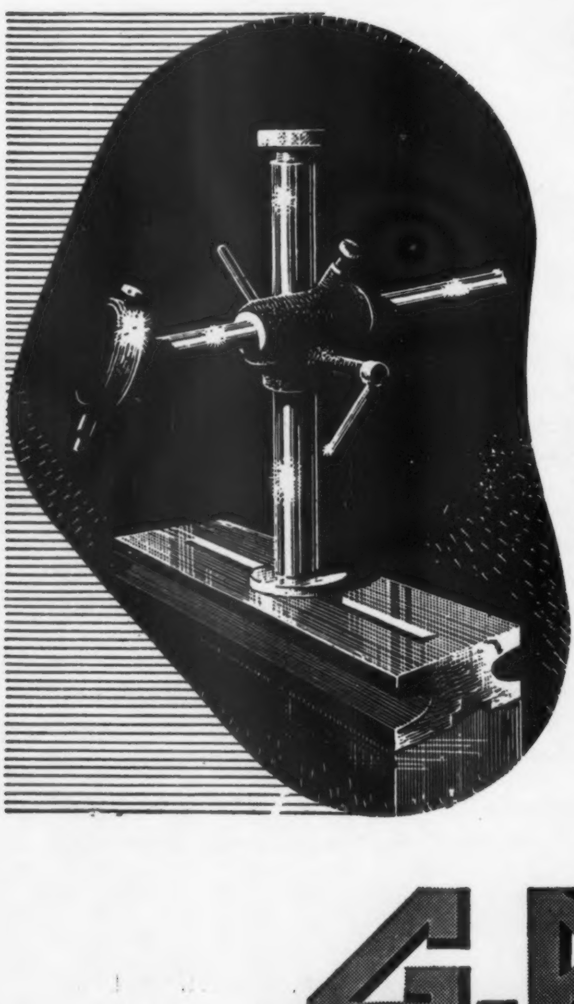

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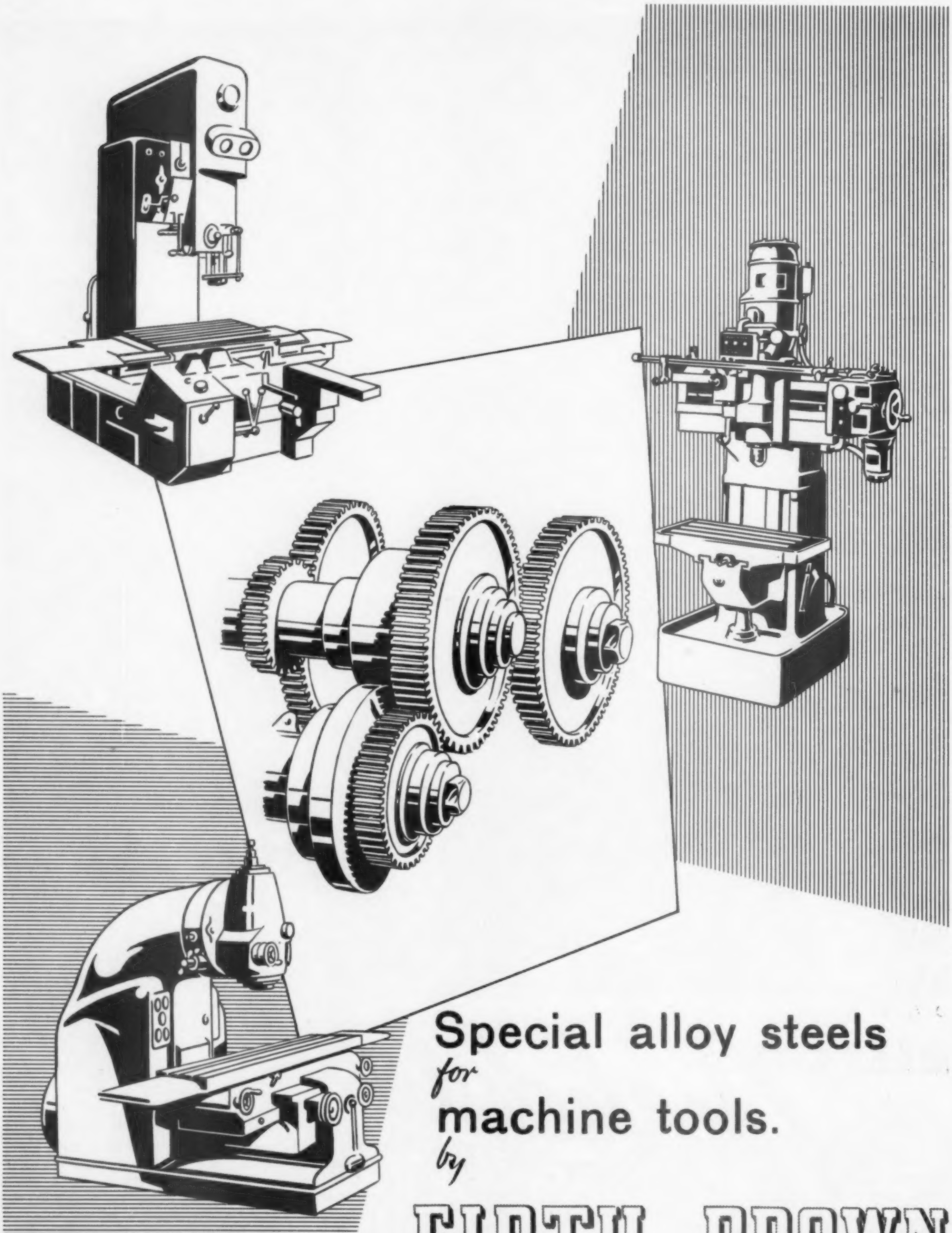
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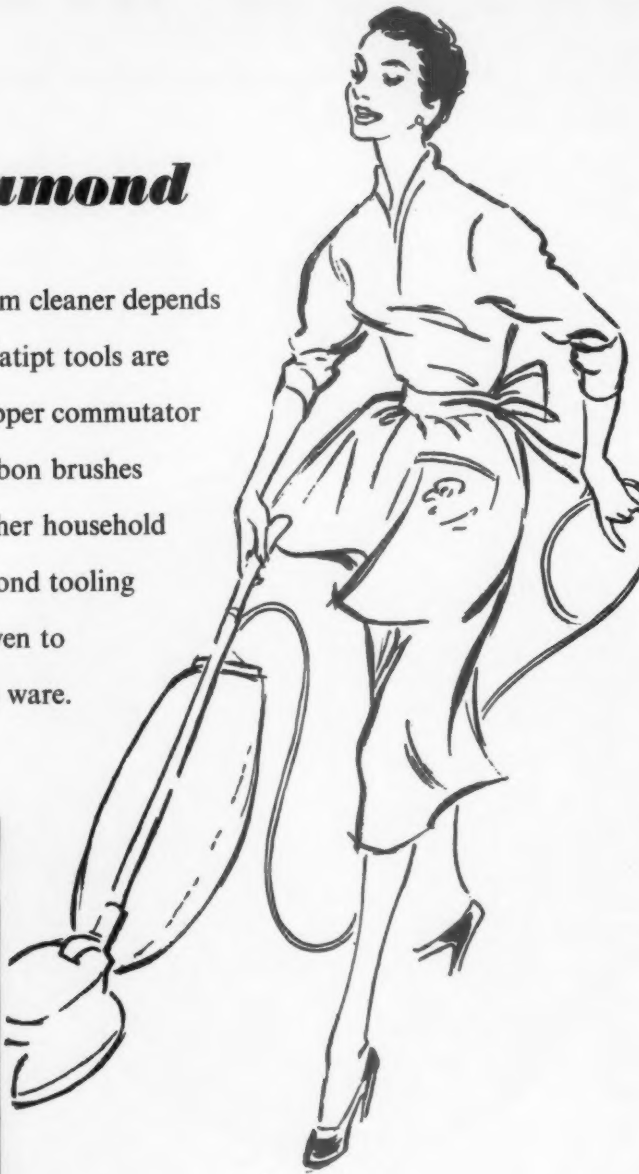

the domestic diamond

The efficiency of a domestic vacuum cleaner depends on the small high speed motor. Diatipt tools are used to finish the surface of the copper commutator so that wear on the contacting carbon brushes is reduced to a minimum. Most other household aids depend in some way on diamond tooling for their efficiency. This extends even to the finishing of aluminium kitchen ware.

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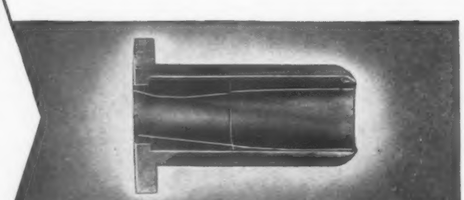
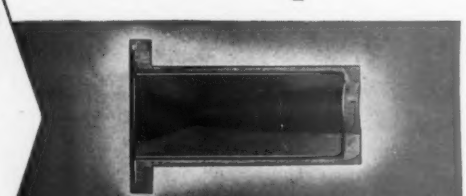
The photographs below show the results of a comparative test made between a Tungsten Carbide Nozzle and a Carbon Tetra Boride Nozzle used with carborundum shot at an air pressure of 75-100 lbs per sq. inch.

The $\frac{3}{16}$″ bore Tungsten Carbide Nozzle was worn to this condition in *two* weeks.



The $\frac{3}{16}$″ bore Carbon Tetra Boride Nozzle with tapered lead-in was worn to this condition in *eight* weeks.



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Range of longitudinal slide	12"

PHOTOGRAPHS SHOW :—

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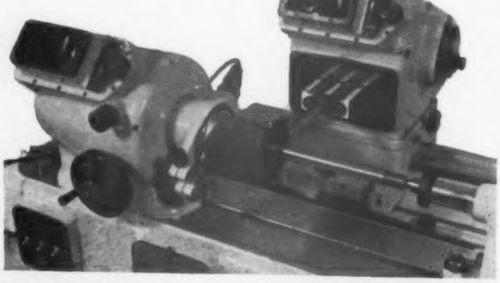
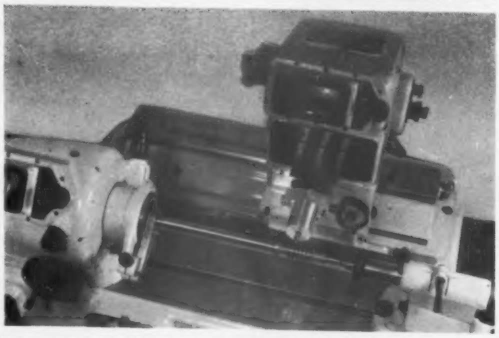
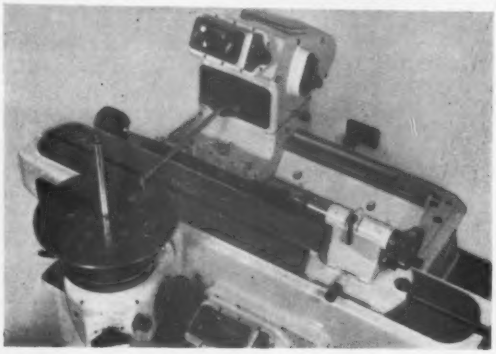
2. *Thread pitch is measured by using a stylus head allowing lateral float of the ball, indicated on a 0·0001 in. comparator. Measuring head is traversed one pitch between readings, the comparator showing any pitch error.*
3. *Alternative mounting position for the optical dividing head enables the profile of flat cams to be checked. In this set-up an extension stylus is being used.*







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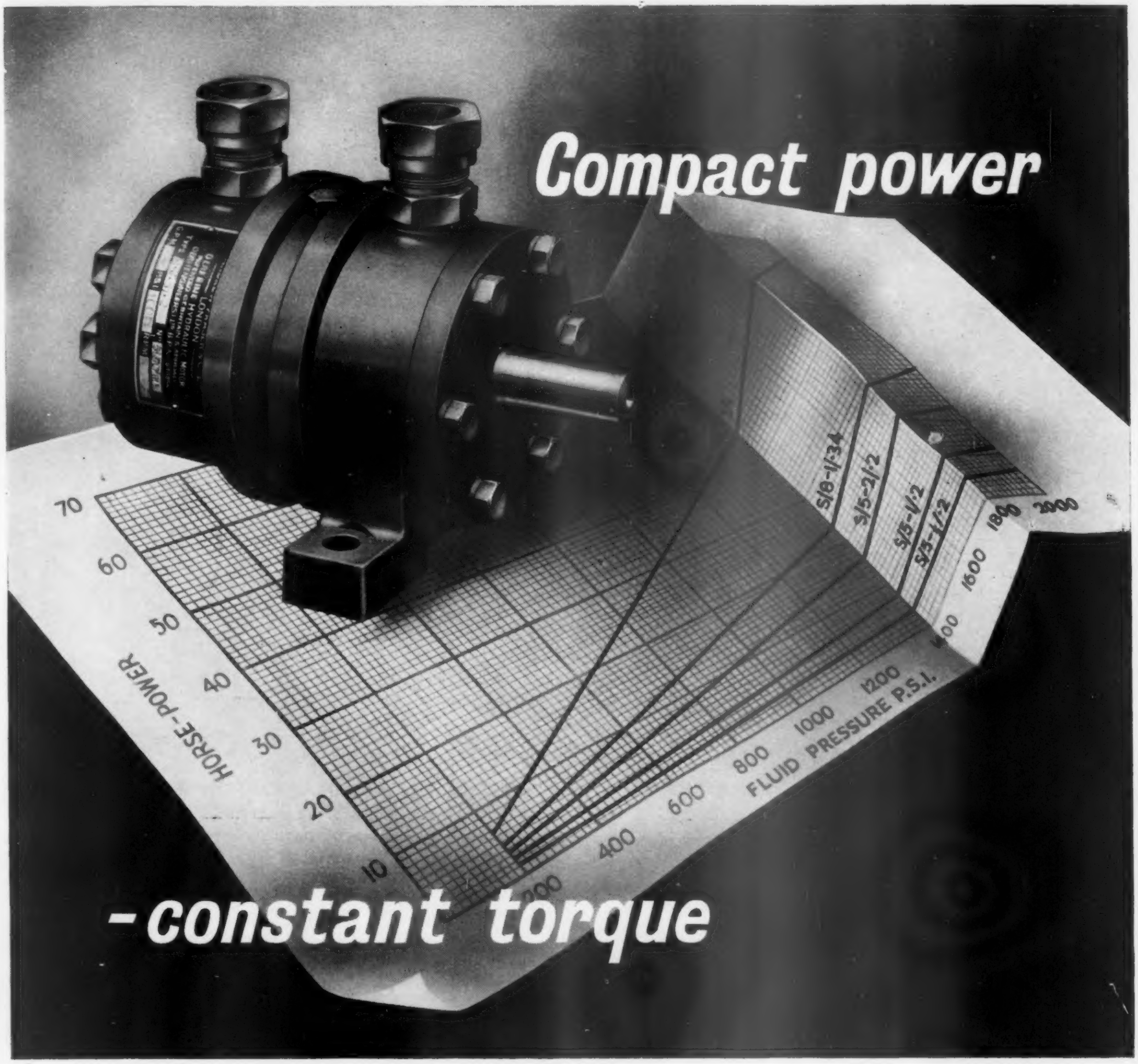

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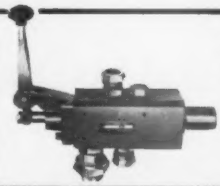

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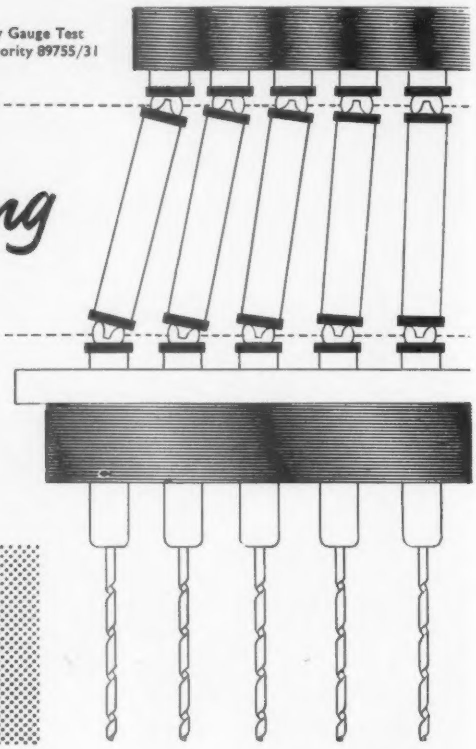

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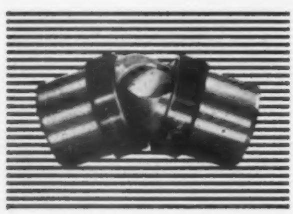

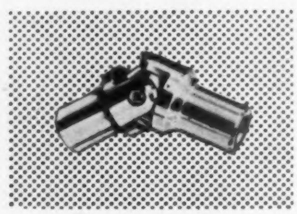

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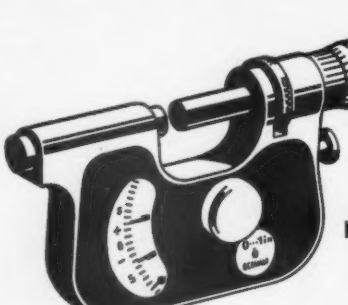

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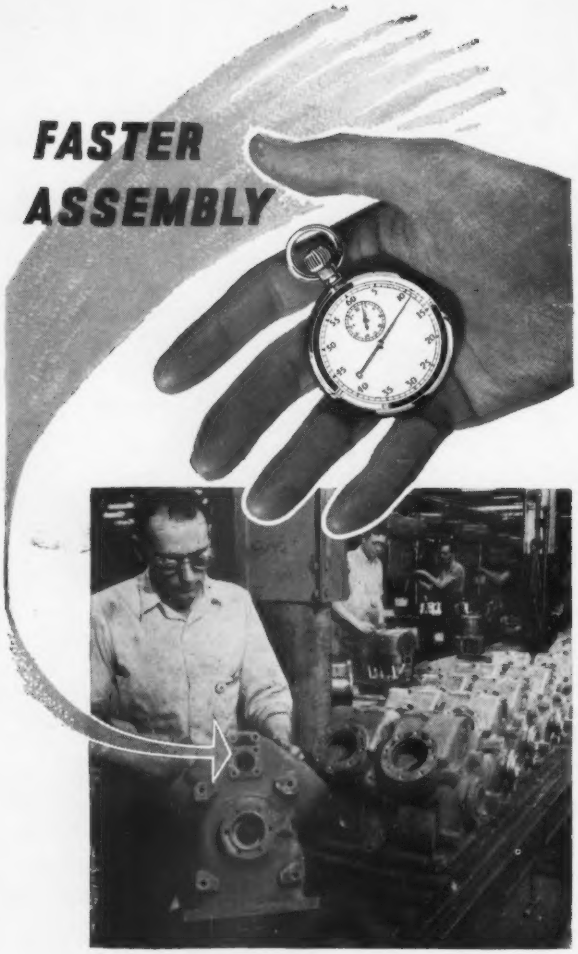

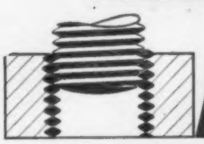

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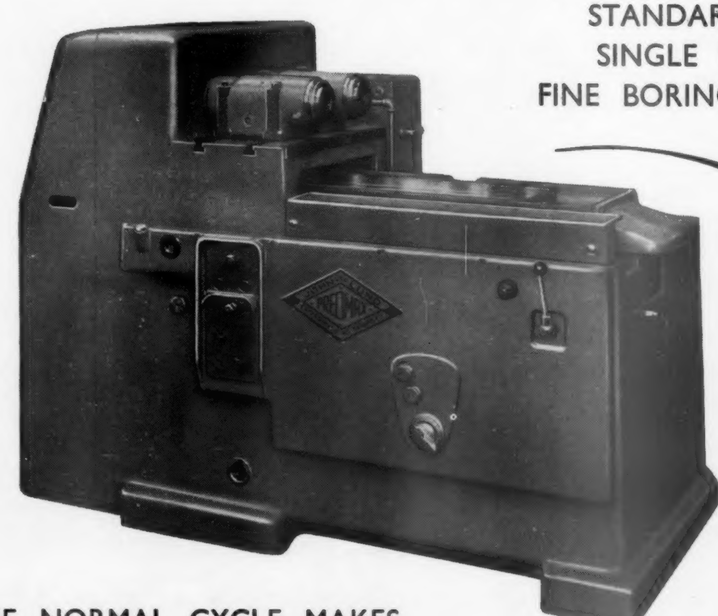

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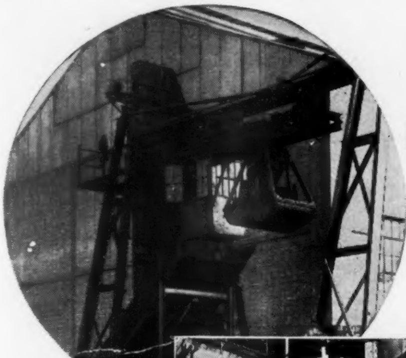

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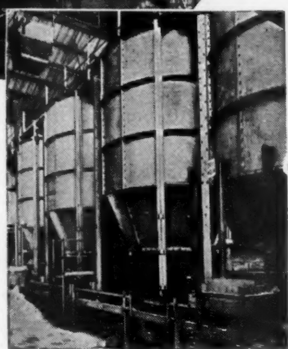

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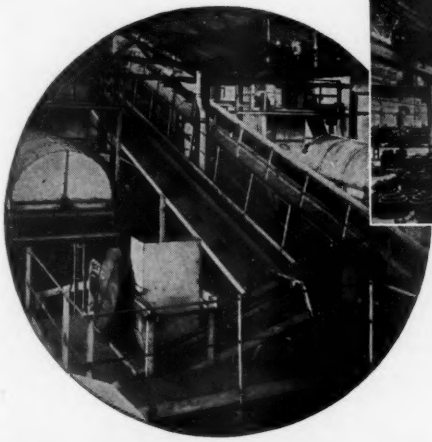

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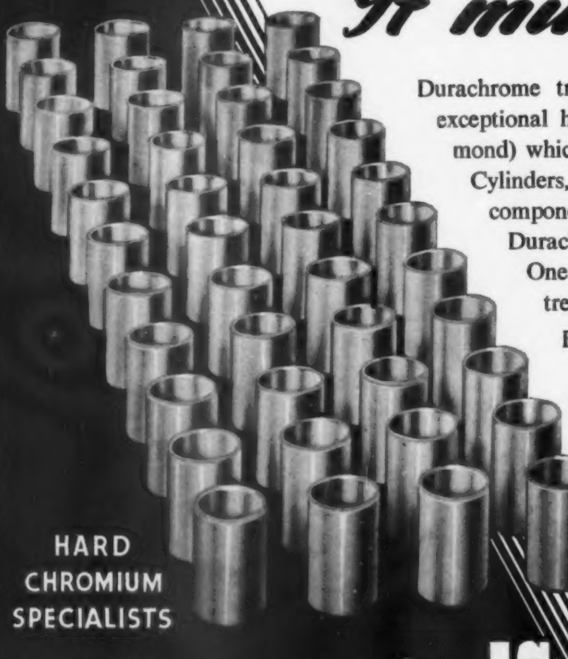

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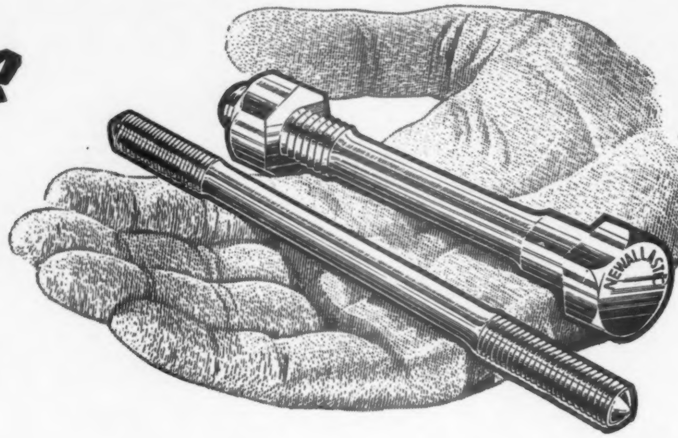

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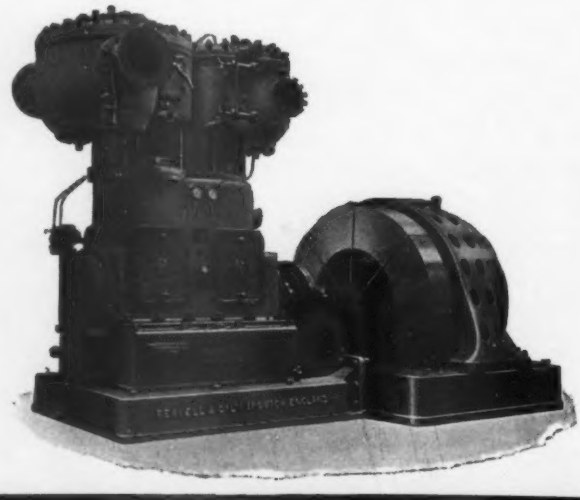

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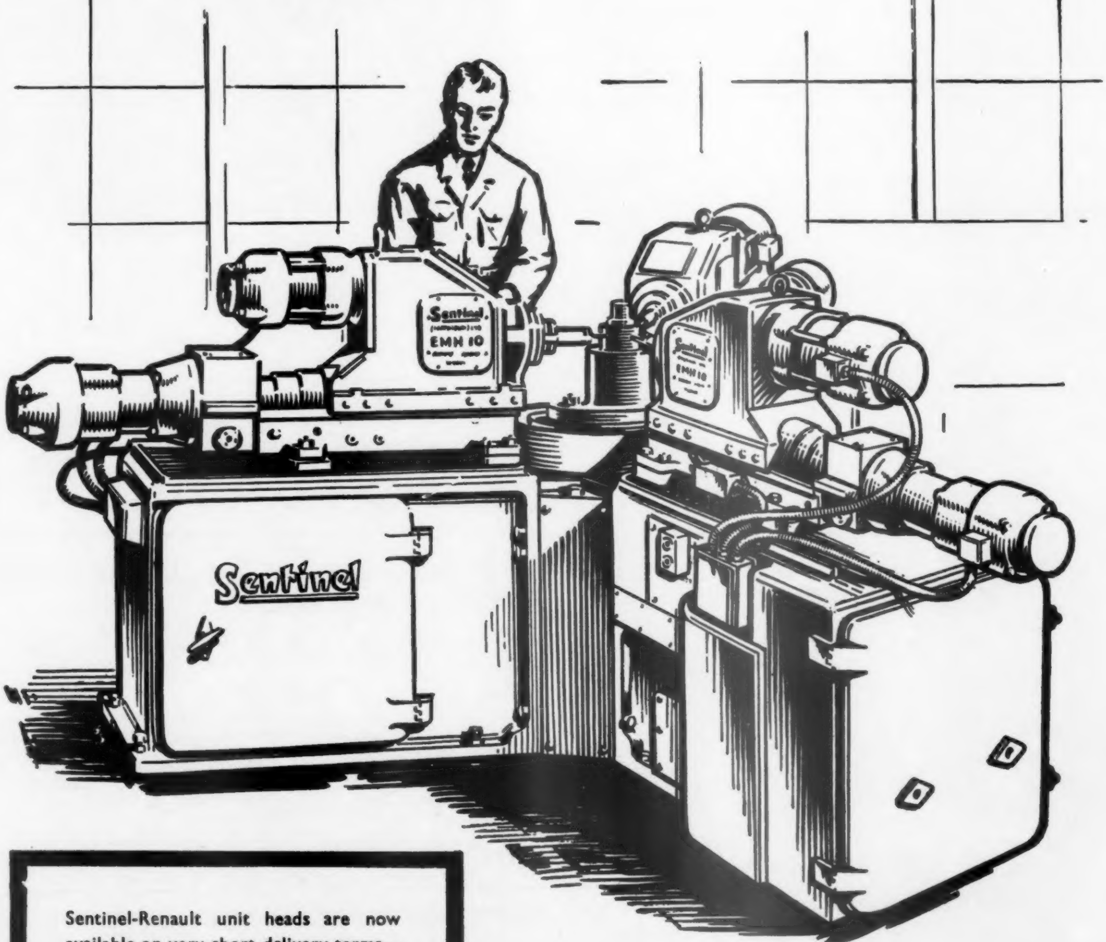

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SS/32/3548

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PATENT CALIPER GAUGE MODEL 52

Each month one of the seven main advantages of this fine precision instrument will be described.

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- Particularly suitable for gauging shouldered work.
- Can be used for either left or right hand threads.
- ★ Particularly suitable for the gauging of acme forms of thread.
- Can be supplied for "GO" only, or "NOT GO" only, or both "GO" & "NOT GO" combined.

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Owing to the design of the anvils and the neat layout of the frame, it is particularly suitable for the gauging of ACME types of thread.

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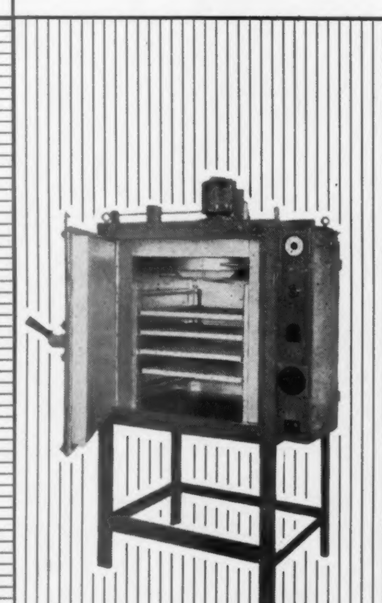

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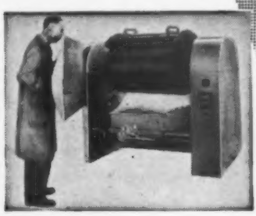
SEND SAMPLES of your products to the Polymotion research and experimental department. We will process them and report on their suitability for barrel finishing. We also offer a barrel finishing service.



Polymotion

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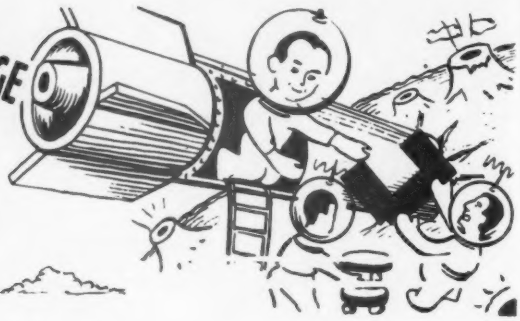

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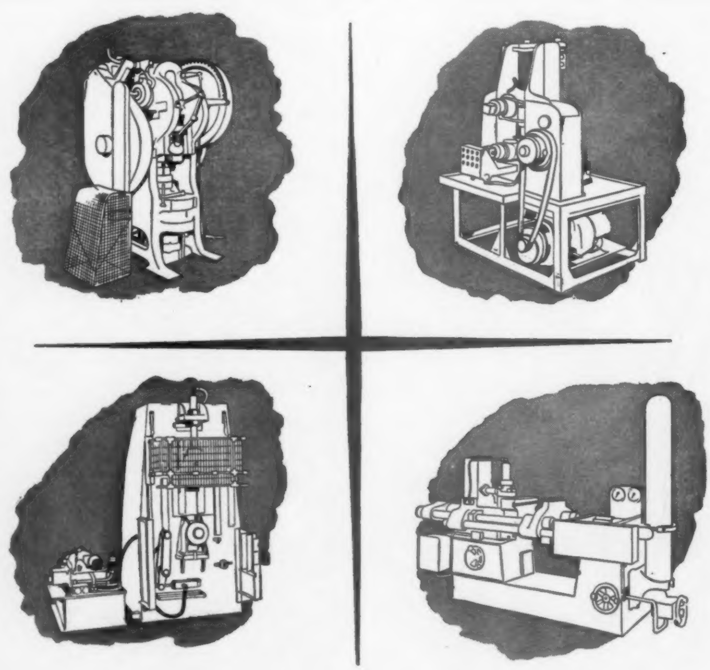

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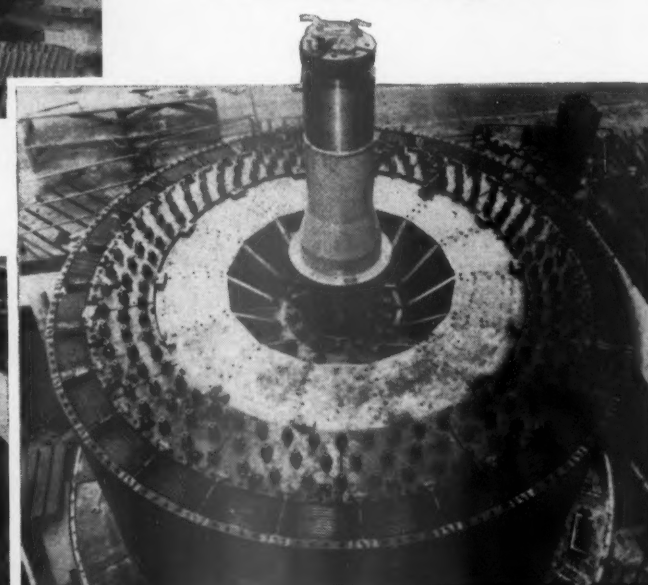
OA/3330

Power in the making...

Stator of the 75,000 kVA 214 r.p.m. vertical generator. One of four ordered for the station.

SAN ESTEBAN

A major contribution to Spanish hydro-electric development is the erection of 19 power stations, comprising a total capacity of 845,200 kVA, which are eventually to be constructed for the Salto de Sil, S.A.. The electrical equipment for the San Esteban station, the largest of the group, is being supplied by Metropolitan-Vickers. The total capacity for this station will be 300,000 kVA, and the M-V contribution to this consists of four 75,000 kVA A.C. Generators, together with the transformers and switchgear.



The rotor of the 75,000 kVA vertical generator.

Assembly of thrust bearing bracket

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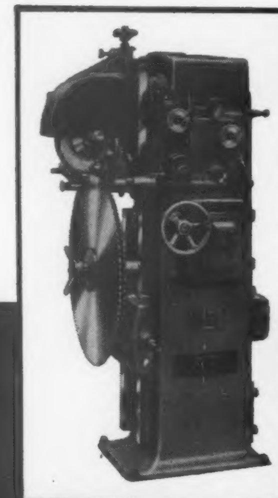

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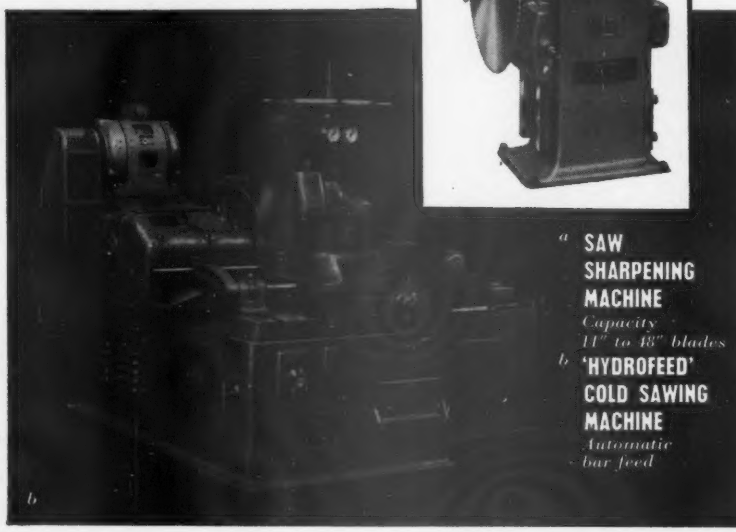

This is an important grease point

The designer puts grease points there for an important purpose, so see to it (1) they are given attention regularly (2) only the correct grade of grease is used.

It pays to ask for ALMARINE, in grades which are equally suitable for grease guns or automatic grease systems and are available in qualities upon which you can implicitly rely.

The latest edition of our booklet " Machine Tool Lubrication " is now available. May we send you a copy ?

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VETA - for hydraulic systems generally

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MTL30

split second controllability

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By means of this Warner unit and Solenoid combination elaborate mechanical gears are eliminated. This is one more process hitherto unobtainable within economic limits that Westool/Warner equipment has now made commercially possible.

Complicated machines are given a new controllability and split second timing with the introduction of Warner clutch-brakes. *Maybe you too could benefit from Warner equipment —ask us.*

* Doffing is the trade term applied to the process of finishing off and removing full bobbins of yarn from spinning frames or similar operations.

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Warner Electric Brakes and Clutches are manufactured in Great Britain under licence by :

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ST. HELEN'S AUCKLAND, CO. DURHAM

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Westool also make Coils, Coil Winding Machines, Transformers, A.C. & D.C. Solenoids, Grinders, Motors, Air Conditioners, etc.

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SLIDEWAY GRINDING

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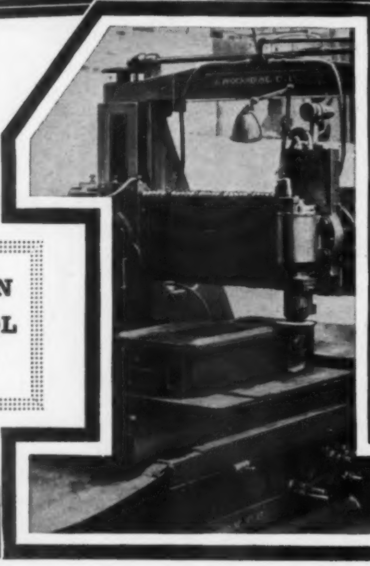
SPECIALISTS IN MACHINE TOOL REBUILDING



HEADS FOR HORIZONTAL AND VERTICAL GRINDING WITH THE BROCKHOUSE UNIT GRINDING HEAD AND TRUING DEVICE.

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★ Rapid and accurate.
★ Slideway Grinding Enquiries invited.

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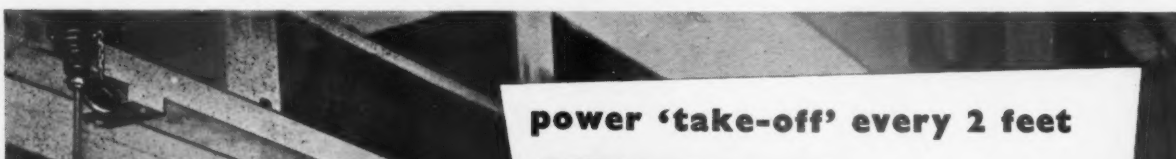
AT 1 SETTING



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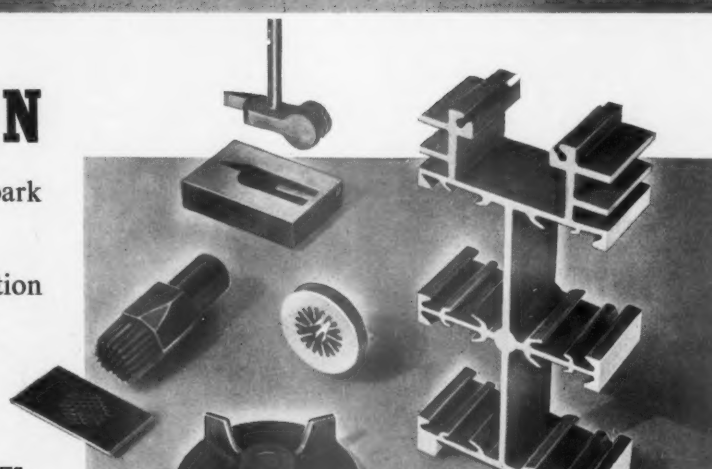
means perfection in the field of spark machining with faster cutting, automatic control, ease of operation and a high degree of precision for all forms of die-making.



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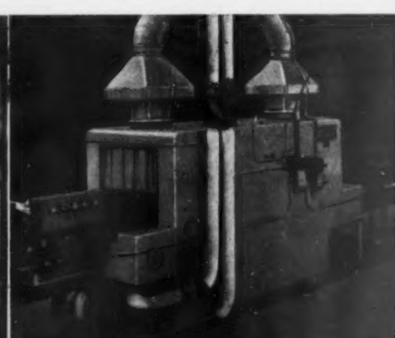
PRIOR TO ASSEMBLY, and BEFORE and AFTER REPAIRS

A 'Junior' type machine supplied to a Midlands Motor Car Works.

Supplied for the washing and drying of Tractor parts. Crank Shafts, Sumps, Pressings, etc.

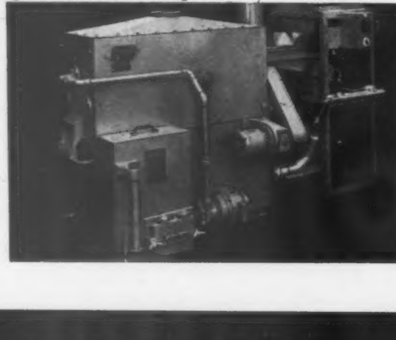


A model 'A' machine, washing parts of motor car engines prior to assembly.

Dawson

DE-GREASING AND CLEANING MACHINES

A Rotary Drum machine for removing swarf and grease from small components.



Dawson Metal Parts cleaning machines are supplied for all branches of the engineering industry. Their chief characteristics are robustness of design, small number of working parts and simplicity of operation. Space only permits the illustration of four of the many types of machines built for quick economical washing and drying of Metal Parts.

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TALYSURF
SURFACE MEASURING INSTRUMENT
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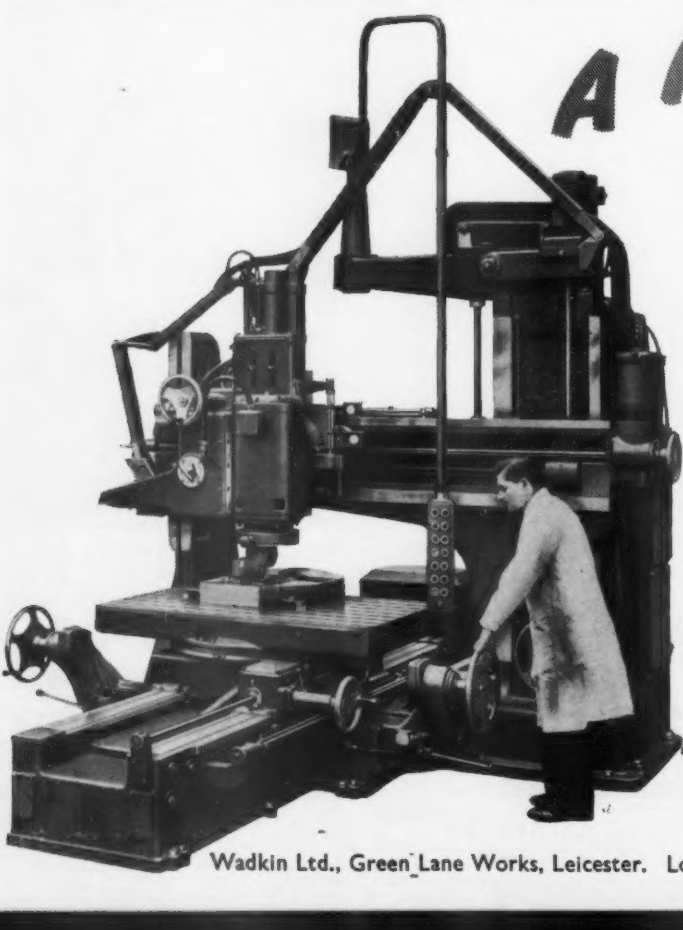

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with speeds from 30-3000 r.p.m.

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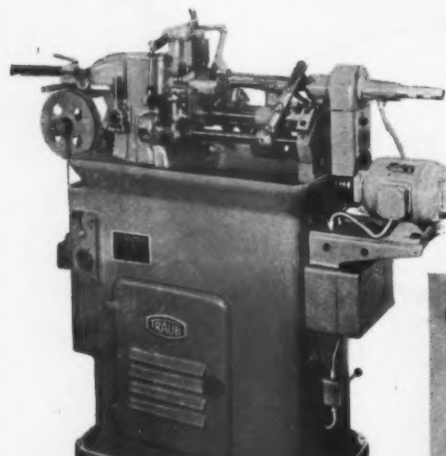

Model A15-A25 with built-in thread cutting attachment

SEE THIS MACHINE ON STAND 45, GRAND HALL
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CAPACITIES:
$\frac{19''}{32}$ - $\frac{13''}{16}$ - $1''$ - $1\frac{5''}{8}$

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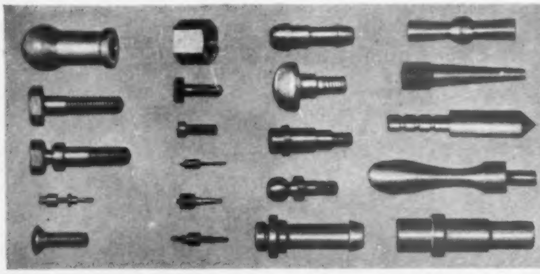

A few examples of the wide range of components which can be manufactured on the TRAUB.

Vertical double slide rest and double drilling attachment.

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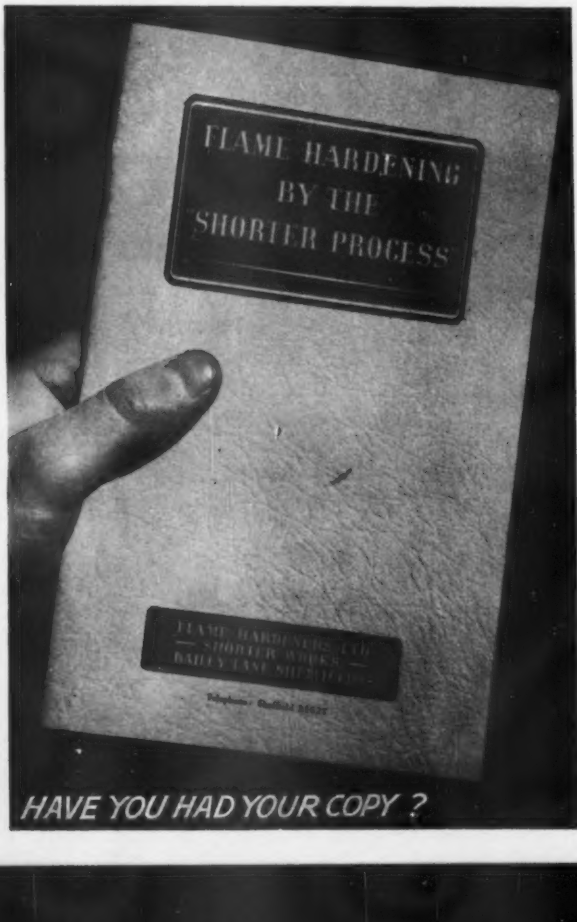

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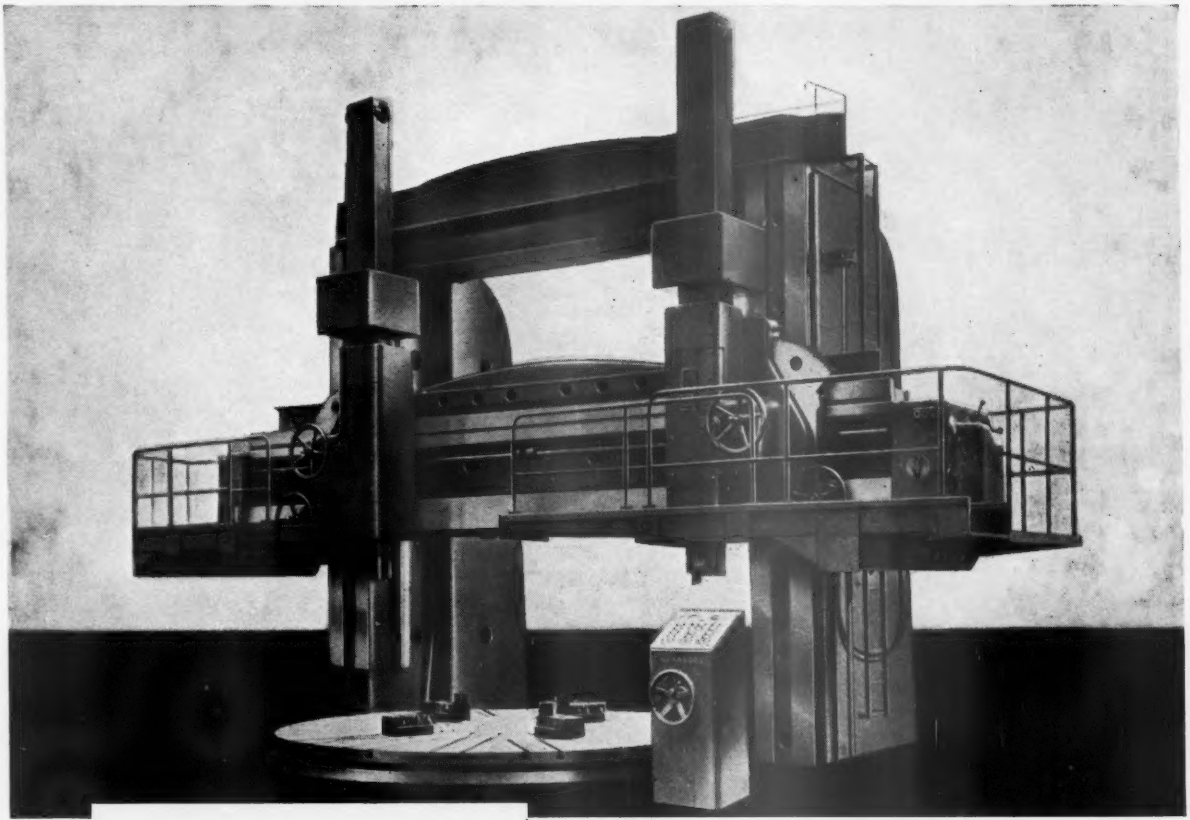

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	SK.40	SK.50
Maximum diameter of turning with Side Arm	13′ 1″	16′ 5″
Maximum diameter of turning with Side Arm lowered below Clamping Plate	13′ 9″	17′ 1″
Diameter of Table	12′ 4″	15′ 7″

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all along the line

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When rivet spinning is not feasible . . .

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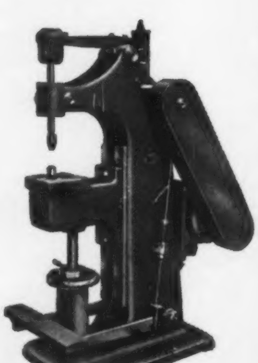

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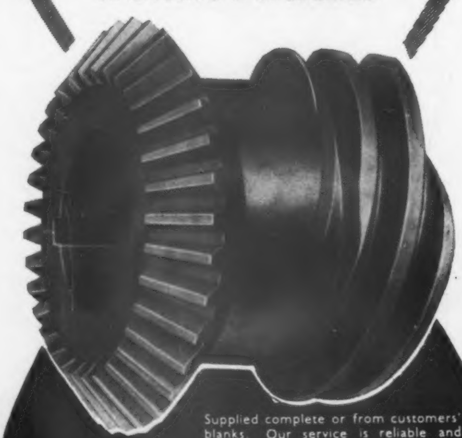

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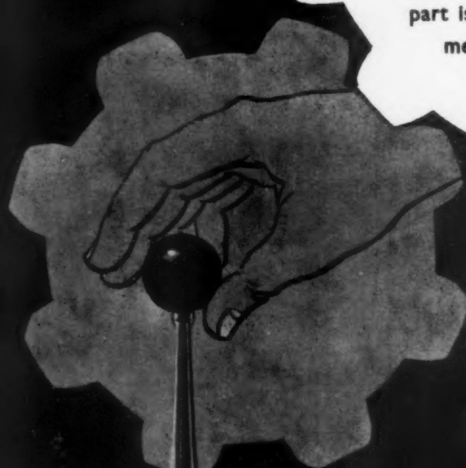

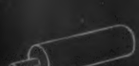

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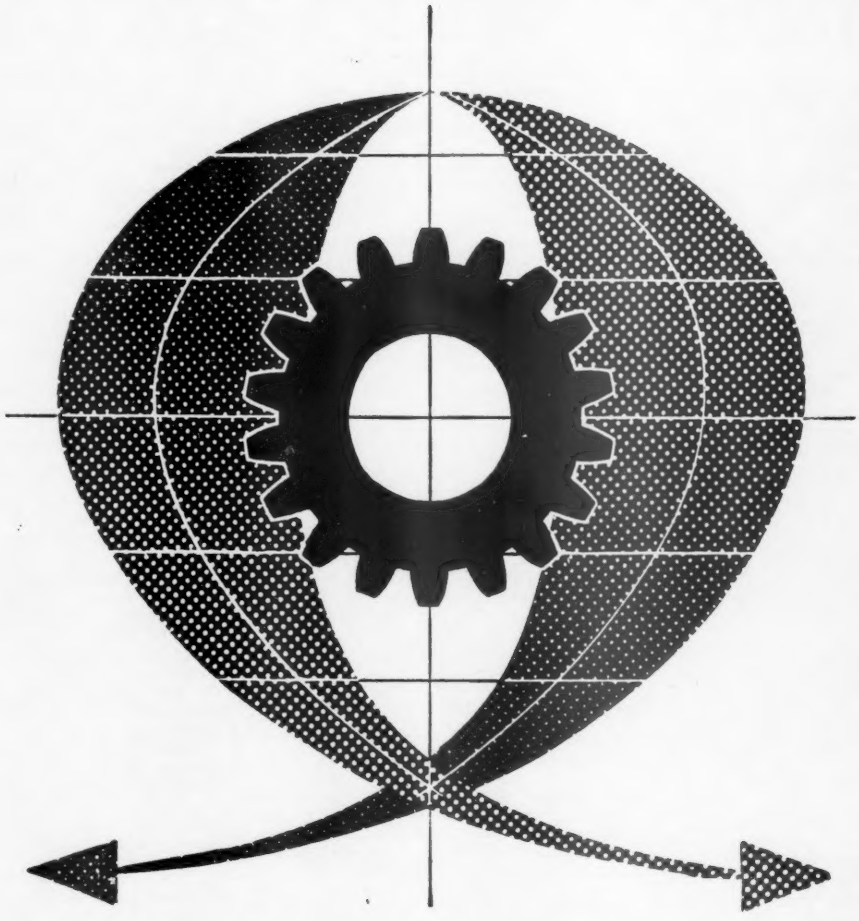

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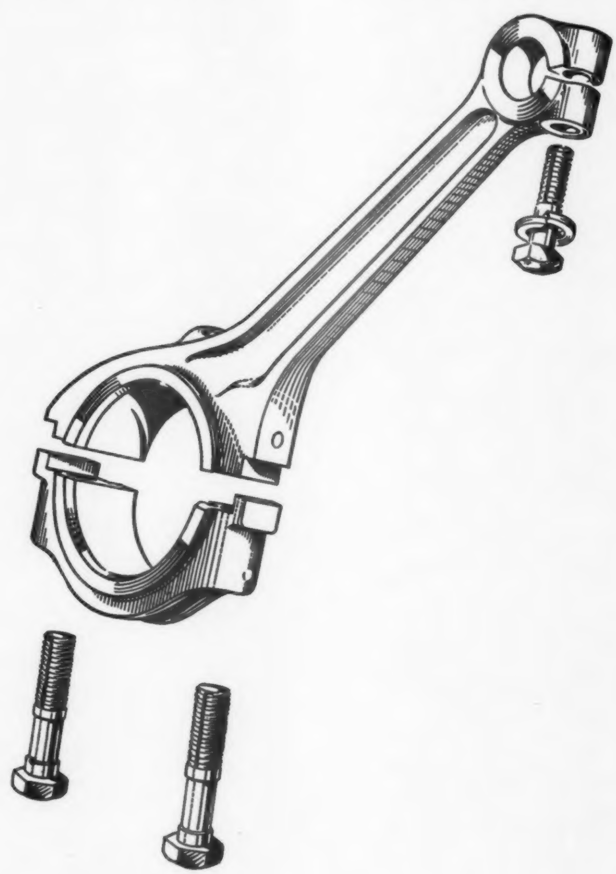

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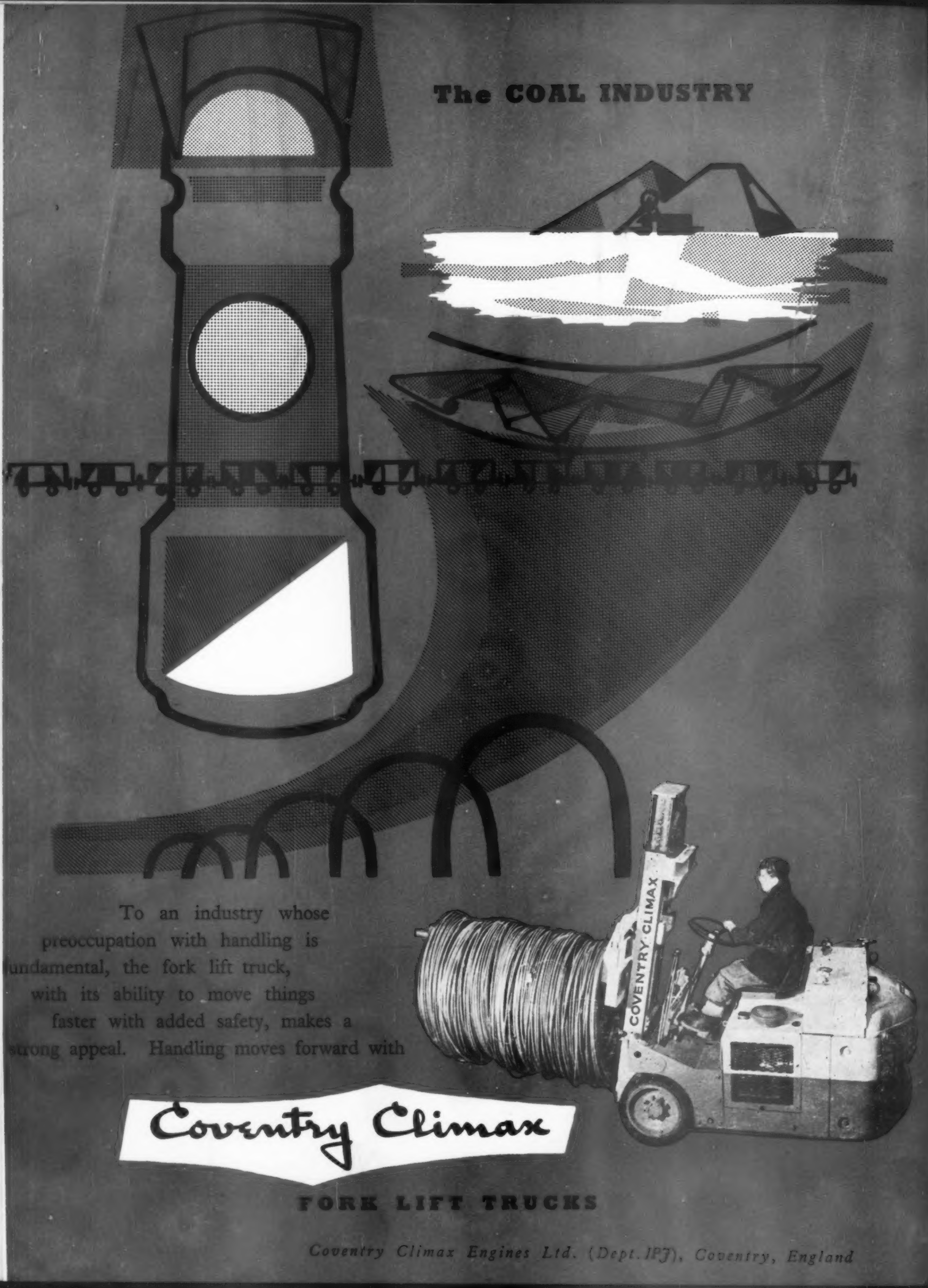

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